# FEASIBILITY OF SHIPBOARD ELECTRONIC DATA PROCESSING

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# FEASIBILITY OF SHIPBOARD ELECTRONIC DATA PROCESSING

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The effects of the current technological revolution, the efforts of the Department of Defense to integrate the stocks of material of the four services, the current operations of the fleet under accentuated readiness conditions, the new techniques of management science and the increased workload of the shipboard Supply Department have made it essential that all departments of the ship and particularly the Supply Department be provided with the necessary tools to permit them to cope with the increased workload problem. The purpose of this paper is to determine whether shipboard Electronic Data Processing (EDP) is feasible and could solve a large portion of the shipboard workload problem. The answer is developed by considering how EDP is already being used in industry and the military, how EDP could be used aboard ship, could the computer and the associated equipment be accommodated aboard ship and what are the characteristics of the computer that would be required for shipboard use. The study concludes that shipboard EDP is feasible, but to obtain optimum results, data processing afloat must be redesigned on a Navy wide basis.

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# CHAPTER I

## THE PROBLEM AND DEFINITIONS OF TERMS USED

The world is in the midst of a breath-taking technological revolution. Some have called it an automation revolution, others a nuclear revolution, still others a computer revolution. This advance in science and technology is so great that it defies description or even imagination, and it has all taken place in the last 17 years. Since 1945, science has developed nuclear powered steam generating plants, nuclear powered ships and submarines, jet engines that drive aircraft more than twice the speed of sound, and computers that can completely control an oil refinery or a manufacturing process. Today man can orbit the earth in space capsules, trips are being planned to the moon, world wide television reception is planned, tiny semi-conductors have replaced large vacuum tube circuits, and on and on. This age was properly described by Mr. Ralph J. Cordiner, then President of the General Electric Company, when he appeared before a Congressional subcommittee on automation, in the following words.

> When the history of our age is written, I think it will record three profoundly important technological developments:
> Nuclear energy, which tremendously increases the amount of energy available to do the world's work;
> Automation, which multiply man's ability to use tools;
> And computers, which multiply man's ability to do mental work.
> Some of our engineers believe that of these three, the computer will bring the greatest benefit to man.[1]

This same revolution has had a tremendous impact on the U. S. Navy. Since 1945, the battleship has disappeared from the active fleet,

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[1]Ralph J. Cordiner, Subcommittee on Economic Stabilization of the Joint Committee on the Economic Report. (Washington: Government Printing Office, 1955), p. 44.

guided missiles costing more than $40,000 dollars have replaced projectiles costing $1,300.[2] Missile launchers have replaced turrets, antiaircraft guns and hedgehogs, computers have replaced personnel in plotting air intercept problems and in determining the ship's navigational position, and nuclear power has replaced the boiler in the propulsion of some ships.

In the future, automation will take over the work of the majority of shipboard personnel, the crew of a nuclear powered submarine will be reduced from 100 to 12 men,[3] and the crew of destroyer escorts will also be drastically reduced in size.[4] Thus the impact of this revolution will be far reaching for the men who sail the seas as well as those ashore.

During the same time that this revolution was taking place, the operations of the U. S. Navy have changed. Due to a clash of ideologies of the major nations of the world and the attempt of larger nations to impose their will upon smaller nations, the United States has found it necessary to keep major fleets deployed at great distances from their normal logistic support bases, and has required other fleets to be maintained in a condition of instant readiness enabling them to deploy to trouble spots on a moment's notice. This type of operation has emphasized logistic readiness and the need for quick accurate replenishment. To help accomplish this end, vast computer networks are being developed in the shore establishments. However, the ships still employ the typewriter and adding machine of World War I to process the paperwork required

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[2]"Terrior," Defense Marketing Service, (Revised 1961), p. 2.

[3]"SUBIC," Naval Research Reviews, August 1959, pp. 1-3.

[4]"Project Suric," Naval Research Reviews, October 1960, p. 6.

to maintain adequate logistic levels.

In the expediency of rapidly building up the air, sea and ground forces during World War II, large stocks of material were procured by each service, catalogued by each service and issued under procedures of the separate services. Shortly after 1955 the Department of Defense introduced an integration program to eliminate duplication of materials within the various governmental departments. This program has already saved millions of dollars, but it has just reached the stage where the real impact will be felt in the fleet. As a result, thousands of cataloging changes are issued annually and ships' personnel are unable to physically process these changes. This results in reduced logistic readiness in our ships. In addition, money is wasted by the ordering of items already on board under another stock number or even by ordering items using a superceded stock number. The scope of the Supply Officer's task has also been increased. Since 1945 he has become responsible for all repair parts on the ship including gunnery, electrical and mechanical, electronic, aviation, special weapons and cryptographic. Thus the Supply Department's work load has increased to the point where it is unable to accomplish its mission effectively with the personnel and tools assigned.

Another product of this age is the development of management science and operations research as an aid to decision making, management and control. This technique employs many of the new sophisticated mathematical techniques such as linear programming, dynamic programming, simulation, statistical control and analysis, probability theory, Monte Carlo analysis, queueing theory, information theory and game theory, all of which can best be applied by solving with a computer.

It is obvious that the technological revolution, the current operations of our fleets, the efforts to integrate the stocks of the four

services, the increased workload of the Supply Department and the new techniques of management science dictate that all departments of the ship, and particularly the Supply Department, be provided with the tools which will allow them to accomplish their mission effectively. The problem takes on added urgency when one considers that as newer, more sophisticated weapons systems and control systems are added to the ships, the number of repair parts will increase as will the military essentiality of the system it supports. As the automatic systems are added, the crews of the ships will be decreased putting the Supply Officer in an untenable squeeze between a rapidly rising workload and decreasing numbers of personnel to process it.

Benefits. The results of this study will prove beneficial to the Navy since it will indicate if the use of electronic data processing afloat is feasible. If it is, this will result in greatly increased logistic readiness of the ships, reduced costs in material carried in inventory, reduced processing costs afloat and ashore, supply departments of ships that are flexible and capable of rapid increase in work load without corresponding increase in personnel, more effective management of shipboard supply departments and reduction of shipboard personnel requirements.

If this study determines that shipboard electronic data processing is feasible, it will benefit the officers and men serving on the ships. It will permit the Supply Officer and Supply Department personnel to carry out the mission of the Supply Department efficiently and effectively. It will permit them to cope with the ever increasing workload, will permit vastly increased Supply Department activity without an increased burden on the personnel, will relieve the Supply Officer of the need to

concern himself with routine repetitive paperwork, and it will allow him to devote his time and effort to better management of his department and the broader logistic concepts of supply.

It is hoped that the reader will benefit from this study, regardless of the results. Prior to this study the writer was so involved in his daily administrative duties that he was quite unaware of the revolution in progress about him. Discussion of the problem of electronic data processing with many officers during the course of the study revealed that they too were completely unaware of the progress being made all about them. Accordingly, this study is being written to be as informative as possible and to point out present uses of computers, new developments in industry and the military, and how computers can be put to use in the future. The language will be simple, to ensure easy comprehension by the reader with no previous knowledge of computers or electronic data processing. By this technique, it is hoped that all readers will personally benefit from this study.

## I. THE PROBLEM

Statement of the problem. It is the purpose of this study to determine if electronic data processing (EDP) in conjunction with a computer is feasible aboard all U. S. Navy ships.

Importance of the study. This problem is of utmost urgency. A revolution in technology is upon us. Ships are becoming more automated every day and the completely automated ship is planned for 1964. Electronic data processing is a possible answer to the increasing paperwork problem. If it is not feasible, other studies must be initiated to find a solution. Accordingly, the problem must receive immediate attention.

## II. DEFINITIONS OF TERMS USED

A description of a computer and a complete set of definitions of terms required to discuss electronic data processing systems and computers is included so that the reader will be able to appreciate the problems involved and the sophisticated and elegant solutions which can be obtained using computers. Some of these terms are defined or explained in over-simplified terms so that while they may not be explicitly and technically correct, they do permit the layman to quickly understand the term or process involved.

Data processing. The function of data processing is the recording, transmission, manipulation and report preparation of transactions. Data processing is of prime management consideration since it is the most important means of exercising control of an organization.

Analog computer. A computer is a device capable of accepting information, processing the information and presenting it in acceptable form. An analog computer processes information by letting the numbers be represented by physical quantities that can be continuously varied, such as the angular rotation of a shaft, the measure of a voltage or the rotation of a gear. The accuracy of the analog computer is limited by those inherent physical characteristics to approximately one tenth of one percent.

Digital computer. The digital computer processes information by counting discrete objects as events. Instead of measuring the magnitude of a current to determine a number as is used in the analog computer, the digital computer determines numbers by determining whether current is flowing or not. The digital computer is much more accurate than the

analog computer, and is therefore used in business data processing. The analog computer is simpler than the digital computer and is usually used for engineering and scientific problems.

Computer functional components. A computer has five functional components. These are input, memory, arithmetic, control and output components. Each will be described separately.

Input components. The input component consists of devices which take information and enter it into the computer for processing. These devices may be punched tape, punched cards, magnetic tape or console typewriter. Since speed is an important factor, it is well to remember the relative speed of these devices. Arranged in order of decreasing speed of transfer, they are magnetic tape, punched tape, punched card and console typewriter.

Memory component. The memory component is a device for storing information to be processed, and the program or sequence of steps describing how to process the information. Memory units generally consist of drums with their periphery magnetized or magnetic cores. When the memory storage within the computer is not large enough to accommodate all information necessary, an auxiliary memory storage device is provided. This is in the form of large reels of magnetic tape, magnetized discs arranged similar to those in a "juke box", magnetic cards, or a large drum magnetized on the periphery.

Arithmetic component. The arithmetic component performs the four basic arithmetic operations as prescribed by the program on information entered into the computer. It can also make comparisons, can determine the larger or smaller of two numbers, and can determine whether a number

is positive or negative.

<u>Control component</u>. The control component coordinates all the actions of the computer and controls the movement of information into the memory from the input devices, into the arithmetic component, out of the arithmetic component to memory and from memory to the output devices.

<u>Output components</u>. The output component has the function of recording and presenting the processed information in the form desired. Output devices in descending order of output speed are: magnetic tape, punched paper tape, punched cards, printed pages. A relatively new output device is a high speed graph plotter which gives the output in visible graph or map form.

<u>Peripheral equipment</u>. Peripheral equipment is output or input equipment used in conjunction with computers. Peripheral equipment may be operated on line or off line.

<u>Off line operation</u>. This term applies to the peripheral equipment. Many of these devices operate at an appreciably slower speed than the computer itself. Therefore, in most computers, the time required to insert data detracts from the computer's actual production time. The slower the input device, the less efficient the installation and the higher the cost of operation. To prevent this, data is converted to a fast input method, usually magnetic tape, independently of the computer operation. Then the magnetic tape is used as an input. The same problem applies to the output of information. Off line operation is the conversion of data from one form to another by devices independent of and not under control of the computer.

On line operation. On line operation is the operation of an input and/or output device as a component of, or under control of, the computer.

Real time. Real time describes computer operation that is simultaneous with an event, such as controlling and altering the trajectory of a missile in flight or updating inventories simultaneously with the transaction. Real time operation is required when it is necessary to manipulate the data simultaneously with the transaction. Real time operation requires 100% reliability of the computer.

Buffer. A buffer is a storage point or delay point that accumulates information or data, while another part of the computer is operating. The input and output of computers are usually buffered to allow an input device to be functioning, that is entering data into the computer, while the arithmetic section is processing other information from memory. At the same time the output device may be writing still different information. A buffer saves time by permitting overlapping operations.

Classes of computers. Computers are divided into classes in accordance with their use. The three major classes, scientific, general purpose and special purpose are described below.

Scientific computer. A scientific computer is one designed for solving complex mathematical problems rapidly. This computer should thus be designed to have maximum computational speed. Relatively slow input and output speeds and small storage capacity can be accepted.

General purpose computer. This computer is used for electronic data processing. Therefore, it should be designed to handle a large volume of transactions involving relatively minor computational work. Thus this computer must have a high input and output speed, a large memory and less

computational ability than the scientific computer.

Special purpose computer. A special purpose computer is one that is designed to perform one particular job well. Examples would be airline reservations, processing checking account transactions, or solving celestial navigation problems. It is to be noted that although a special purpose computer is designed to perform one particular task well, it can still be used for other jobs, but usually with less efficiency.

Classification by size. Computers are sometimes classified by size, with the size actually determined by price. Large scale computers usually cost over $1,000,000, medium scale computers usually run between $500,000 and $1,000,000. Small scale computers usually cost less than $500,000. Then there are the desk size computers which sell for less than $100,000.

Transactions. The transaction is the fundamental unit of raw material of data processing. It usually is identified by descriptive information and quantitative information.

Data manipulation. Data manipulation usually refers to the arrangement of information into proper sequence, reference to file information, logical functions which consist of precise determination of procedures or subprocedures to be followed, arithmetic functions and updating of the file information to reflect the transaction.

Systems analysis. A systems analysis is a complete and thorough review of the entire data processing system under consideration consisting of a review of the present organization structure and tracing of all flows of information from initial point to final action. The purpose of systems analysis is to improve the organization structure, eliminate

duplication and unnecessary work, and determine where data processing can be improved.

Flow chart. A flow chart is a graphical representation of a sequence of operations usually using prescribed symbols.

Instruction. An order (usually coded in numerals) which tells the computer to perform a specific operation with specific data.

Program. A program is a sequence of instructions which accomplishes a desired task or solves a problem. The program is usually made up from the flow chart.

Stored program. A stored program denotes that a prearranged program has been devised and placed in memory in the computer, enabling the computer to process any data entered without further instructions.

Compiler. A compiler is a computer program that converts a program written in a universal program language to the language that a specific computer understands.

Hardware. Hardware is the mechanical, magnetic, electric and electronic devices from which a computer is constructed.

Software. Software refers to the automatic programming aids that simplify the task of telling the computer "hardware" how to do its job. Software is thought to consist of three basic categories: assembly systems, compiler systems, and operation systems.

Cryogenics. Cryogenics refers to the low temperature properties of matter and involves the operation of equipment in gases, such as helium and nitrogen, in a liquid state creating temperatures ranging from -200 F

down to -4[illegible] F. This cold temperature causes molecules within an object to come to a stop, thus giving the material abnormal qualities such as superconductivity and resistance to wear.

Redundancy. Redundancy is the use of extra units or extra circuits which duplicate those already in use. In case of failure of the main unit or circuit, the redundant unit or circuit takes over and keeps the machine in operation.

Numerical control. Numerical control (abbreviated N/C) is a system whereby a part to be machined from stock is described in mathematical terms. These terms are fed into a computer which interprets them as to milling operations required. The computer records the required operation on punched tape which is then used as an input to the milling machine and the part is machined without human aid to a greater accuracy than possible if done by hand.

Model. A model is an abstraction. It helps to describe the situation in real life under investigation and in a sense attempts to duplicate it. A model could be a schematic drawing, a three dimensional physical model or a mathematical model (formula). When dealing with computers, a mathematical model is usually developed. The variables of the model are then manipulated and the effects on the results observed.

Sequential access files. Sequential access files refer to computer processable files of information which have the property that the first record in the file must be read before the second and the second before the third, and so on. A magnetic tape is a good example of sequential access files.

Random access files. Random access files refer to computer processable files which are characterized by the ability to skip around within the file and to extract information desired with no particular regard to the sequence in which information was loaded in memory or extracted from memory. A magnetic core is an example of random access files.

Bit. A bit is the abbreviation for "binary digit." The binary system is a numerical system wherein there are only two numerals, namely 0 and 1. This system is the basis of a digital computer and all information within the computer is recorded in binary form, which has only two possible states. For example: a 0 may represent an open switch (no current flowing) while a 1 would represent a closed switch (current flowing). Bits are combined in groups of three, which designate octal numbers (positional number notation to base 8) as opposed to the decimal system (positional number system to base 10.) Typical coding is as follows:

| Decimal | Octal | Binary |
|---|---|---|
| 0 | 0 | 000 |
| 1 | 1 | 001 |
| 2 | 2 | 010 |
| 3 | 3 | 011 |
| 4 | 4 | 100 |
| 5 | 5 | 101 |
| 6 | 6 | 110 |
| 7 | 7 | 111 |
| 8 | 10 | 1000 |
| 9 | 11 | 1001 |
| 10 | 12 | 1010 |
| 11 | 13 | 1011 |
| 12 | 14 | 1100 |
| 13 | 15 | 1101 |
| 14 | 16 | 1110 |
| 15 | 17 | 1111 |
| 16 | 20 | 10000 |
| 24 | 30 | 11000 |
| 32 | 40 | 100000 |
| 40 | 50 | 101000 |
| 48 | 60 | 110000 |
| 56 | 70 | 111000 |
| 64 | 100 | 1000000 |

Information Retrieval. Information retrieval is a system of classifying with key words and indexing large quantities of information and storing the classification, index and brief description in the computer so that rapid access is ensured to all information concerned by querying the computer with any of the key words.

## III. ASSUMPTIONS AND LIMITATIONS

Assumptions. It is assumed that computers now installed in ships for navigation, weapons control and tactical data systems will not be able to offer sufficient free time to accommodate all data processing requirements of the ship. If any computer installed aboard a ship is not used entirely for its primary purpose, it should be made available during its free time for other uses.

Limitations. No effort will be made to attempt a systems analysis of shipboard data processing. Early in the study it became evident that efficient shipboard data processing must be based on a total systems concept which would embrace the data processing of all departments of the ship and the shipboard procedures and reporting requirements prescribed by the various management bureaus. Obviously, any systems analysis would have to be conducted by a committee of personnel representing the cognizant bureaus, operational commanders and personnel familiar with all phases of the shipboard data processing of all departments of the ship.

As stated earlier, this paper is written in as simple a language as possible in an attempt to give complete understanding to the problem and its solution to all readers. As a result, over simplifications may occur which are not exactly correct. However, the need for simplicity and complete understanding of the basic problem overshadows any minor departures from technical operational techniques of the computer and its systems.

## IV. REVIEW OF THE LITERATURE

Literature on electronic data processing and computers in general is plentiful. However, the technology and state of the art is advancing so rapidly that it is difficult to keep current with the latest improvements. The trade magazines specializing in computers and electronic data processing are far more useful than books.

There is little literature on actual government (military and otherwise) experience or progress, despite the fact that the federal government has been and still is the leader in the use of scientific and data processing computers. Again, the best information can be obtained from the trade journals and government periodicals.

Research significance. No other research papers in this area were located.

Sources searched. The following sources were searched:

1. Government, military and commercial technical, business and management periodicals from 1950 to date.
2. Technical research reports on the subject that were available.
3. The current information pamphlets from all major computer manufacturers.
4. The most recent books on the subject which are also listed in the bibliography.

## V. ORGANIZATION OF THE REPORT

In order to determine whether shipboard EDP is feasible, the following questions must be answered:

Can the shipboard administrative workload be adapted to EDP?

Can the EDP system with its computer and peripheral equipment be accommodated aboard ship physically and organizationally?

Is there a computer that can fill the requirements of shipboard EDP?

Chapter II of this report gives a brief history of computers, how they operate and how they are being used in industry and the military services. Chapter III describes how the shipboard administrative workload could be adapted to EDP. Chapter IV determines whether the computer could be accommodated aboard ship. Chapter V describes the type of computer required for shipboard EDP and Chapter VI is the summary and conclusion.

# CHAPTER II

## THE COMPUTER IN INDUSTRY AND THE MILITARY

### I. A BRIEF HISTORY

The history of the computer is characterized by a slow start thousands of years ago and sporadic interest until 1945 when the computer field exploded with phenomenal growth and a far reaching impact on our way of life.

The abacus, which was in use in 500 AD in Egypt and the Middle East, may be considered the first digital computer. It is interesting to note that it employed the same bi-quinary number system which was used in the most popular computer of the late 1950's, the IBM 650.

The slide rule was invented in 1630 and used logarithms and a logarithmic scale which had been developed earlier by Napier to perform multiplication and division. The slide rule may be considered the first analog computer since it worked on the basis of physical measurements to perform mathematical functions as do our modern analog computers.

In 1642, a tax collector in Paris was having difficulty totaling his accounts, so his son Blaise Pascal decided to help and built the first mechanical adding machine. This machine could just add and subtract. In 1673, Wilhelm Leibnitz, the German philosopher and mathematician, succeeded in improving on Pascal's machine and built a machine that could mechanically multiply and divide.

The generally accepted "father of the computer" was a mathematics professor from Oxford University named Charles Babbage. In 1812 he started work on a machine he called a Difference Engine. He never completed this machine because he was unable to have the parts manufactured with sufficient precision to make his Difference Engine function accurately. Consequently he devoted more time on improving manufacturing processes than

he did on computers.

In 1833 Babbage was back in the computer field and conceived the Analytical Engine. This machine could be called the first general purpose computer since it used punched cards to sequentially control the arithmetic operations it performed. The information was stored by use of mechanical wheels and the punched cards dictated the sequence of manipulation. Again Babbage was unable to complete this machine because of the same engineering problems that had plagued his Difference Engine. However, his son later completed both engines.

The next milestone in the development of the computer resulted from the heavy workload in the U. S. Census Bureau. The Bureau found that the population had increased so rapidly that it was impossible to complete the collection and posting of one census, before another one was completed and ready to be processed. So in 1889, Dr. Herman Hollerith invented and built a sorting and computing machine which would collect the information from punched cards. (These cards were initially called Hollerith cards after the inventor, but are now called electric accounting machine-EAM-cards.) This machine was used successfully for computing the 1910 census. Mr. Hollerith later left the Census Bureau and became associated with a commercial firm which later became the International Business Machines Corporation (IBM).

The U. S. Navy also played an important part in the development of computers. The first true analog computer produced in quantity was made for the U. S. Navy in 1915 by the Ford Instrument Company. This was called the MKI Range Keeper or the "Baby Ford" which was the forerunner of the modern Navy fire control computer. This range keeper was replaced by the more complex Mark I computer which, in conjunction with the Mark 37 fire control system, contributed immeasurably to the success of naval gun

batteries during World War II.

In the late 1930's, Dr. Howard Aiken of Harvard conceived of a machine similar to Babbage's using the principle of sequential control. The start of World War II put pressure on the military to develop computers that would solve the weapons trajectory problem. The aid of several universities was enlisted and Dr. Aiken of Harvard pushed his Automatic Sequence Controlled Computer, more commonly known as the Harvard Mark I, to completion in 1944. This computer employed an electromechanical system and its sequencing was controlled by coded punched paper tape. This computer is still in use today.

At the same time, the Moore School of Electrical Engineering at the University of Pennsylvania was engaged in a similar project for the military. Many persons were involved in this project including von Neuman, Mauchly, Eckert and Goldstine. They completed the Electronic Numerical Integrator and Computer (ENIAC), the first truly electronic computer in 1946.

The Mark I and the ENIAC which contained 18,000 vacuum tubes were the beginning of our modern computer age. It is interesting to note that the first problem worked on the Mark I took two weeks. This same problem would have taken 100 man years if worked by hand. The ENIAC was much faster than the Mark I and a transaction that took three tenths of a second to perform in the Mark I took only five-thousandths of a second in the ENIAC.

The race was on. Dr. John von Neuman developed the use of internal memory, rather than sequencing, in 1945, and the Electronic Discrete Variable Automatic Computer (EDVAC) was developed. This was followed in 1949 by the Electronic Delay Storage Automatic Computer (EDSAC) built at Cambridge University, the Bureau of Standards Eastern Automatic Computer

(SEAC), and the Eckert Mauchly Corporation BINAC.

The first computer to be mass produced was the UNIVAC which was delivered to the Census Bureau in 1950. In 1953, International Business Machines Corporation's Model 701 was placed on the market and the computer revolution was underway.

Starting with the few machines in use in 1953, the market has exploded. Late in 1957, there were 200 large-scale computers and 600 small and medium scale computers in use. By late 1959, these had grown to an estimated 400 large-scale computers and over 2,000 small and medium computers.[5] In 1960, the total number of computers increased to 4,500 and in 1961 the figure was increased to 14,453 in addition to over 8,000 unfilled orders.[6] In 1962 International Business Machines reported that they had firm orders for over 7,000 of their Model 1401 computer.[7]

## II. DESCRIPTION OF A COMPUTER

Operation. The computer is simply an improved desk calculator just as the missile is an improved projectile. In order to use a desk calculator it is necessary to enter the number to be manipulated by depressing the keys. This action is comparable to the input in a computer. After the numbers are entered into the desk calculator it is necessary to depress the key or bar which will cause the numbers that were introduced to be manipulated (added, subtracted, divided or multiplied). This action is similar to the program that is placed in the computer. Similarly, the

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[5]E. Wainright Martin, Electronic Data Processing An Introduction (Homewood: Richard D. Irwin, Inc., 1961), p. 2.

[6]Computers and Automation, Vol. II, No. 4, (April 1, 1962), p. 14B.

[7]"1401 Sales Booming," Datamation, Vol. 7 No. 10 (October 1961), p. 15.

appearance of the answer on tape, or in a register window of the calculator is comparable to the output of the computer. So the computer is actually only a sophisticated calculator in which the manipulation must be determined in advance and entered into the computer before the data to be manipulated is introduced.

To get an even better idea of how a computer functions, a simple addition problem will be traced through the computer. The program or directions to the computer are first written, converted to machine language and put on a tape which is then used as the input to the computer. The program is then entered into memory. Next, the numbers (A & B) which are to be added together are also entered into the memory of the computer by tape. When the start button is depressed the control section of the computer takes control, reads the program, and operates the computer accordingly. It first directs that the first number A be removed from storage and placed in the arithmetic register in the arithmetic section of the computer. The control section then directs that number B be taken from storage and added to A in the arithmetic register. It then directs that the new number C be returned to storage and finally the control section directs the output section to punch the answer C on tape as an output. It should be noted that inputs go only to storage and all outputs come only from storage. Both the program and the data to be manipulated are stored in the internal storage. The control section, by reading the program, controls the internal functioning of the computer, directs data from storage to the arithmetic section and back to storage and tells the arithmetic section what operation to perform on the data.

Critical Characteristics. Different model computers have different characteristics which affect their operation and determine their most efficient use. Unfortunately, no two manufacturers apply the same meaning

to the various characteristics. Therefore, in talking about a characteristic for any specific computer, it must be determined how the manufacturer defines the characteristic under consideration. The three critical characteristics of a computer are speed, storage capacity and word length. Each will be discussed separately.

1. Speed. Since the acknowledged purpose of a computer is to increase the speed of calculating a problem or processing data, the faster the computer is internally in processing the data, the more efficient the computer, and the less expensive it is per unit of time or per document processed. Accordingly, all speeds are important. This includes the speed of input and output, the speed to perform certain arithmetic and logic operations, and the speed to transfer information in and out of storage.

2. Storage. Another important characteristic is storage capacity. Remembering that both the program which controls the manipulation of the data and the data itself must be stored in the memory section, it is essential that storage capacity be great enough to permit complete programs and the normal data load to be stored in the computer simultaneously. Obviously if the storage is too small, duplicate runs will have to be made with the data thus doubling the processing time.

3. Word length. Each storage location in the internal memory can only process a word of a prescribed number of characters or numerals which is determined by the design of the computer. Some computers use five digit words and others use as many as sixteen digits. Thus all manipulations within the computer must be in units of alphabetic characters or numerals of word length or less. If it is necessary to manipulate a unit of numerals or characters greater than one word length, it will be necessary to use two word lengths. This can be very wasteful of storage space. For example: if it is desired to enter into the computer the number

123456, and the computer has a word length of five, it will be necessary to split the number into two parts and put 00001 in the first memory cell and put the 23456 in the second memory cell. Accordingly, storage space for four numerals in the first cell has been wasted. Some computers in use today have overcome this problem by utilizing variable word lengths. In this case the smallest word that can be manipulated is one digit. It is also necessary to carefully note how the manufacturer defines word length. In some instances, one alphabetic character takes the space of two numerals in a word. Thus the effective storage space would be quite different depending upon whether characters or numerals were being discussed. Likewise, the length of the word affects the net storage space when comparing computers. For example: two computers may both have storage capacity for 16,000 words, but if the word length in one computer is five digits and the word length in the second computer is ten digits, the latter has twice the net storage space of the former. Thus, the word length in a computer is also critical, and it is essential to know how the word length is defined by the manufacturer before it can be used as a point of reference.

## III. USES IN INDUSTRY

Mr. Alfred F. Wilson, executive vice-president of Minneapolis Honeywell Regulator Company, told a large press gathering:

> We are beginning a clerical and industrial revolution-and a management revolution as well and the tempo and pace of the revolution will be far greater than those of the first revolution. This revolution will affect every aspect of our business, of our economy, of our education system, of our society as a whole. We can insure that these changes are planned in advance-or we can pretend nothing is happening and face the strong possibility of having to take emergency

measures in a crisis situation later.[8]

The revolution Mr. Wilson was referring to is the result of the application of the computer for electronic data processing, decision making, control of production and scientific problem solving. This new science has been called such sophisticated names as "artificial intelligence", "bionics", "intellectronics", "cybernetics", and many other illuminating titles. However, these terms all refer to the increasing use of computers as tools of mankind. This revolution differs from the earlier one in that in the first industrial revolution the machine reduced man's labor requirements, while the latest revolution has reduced his clerical requirements. The graph shown in Figure 1 indicates the tremendous increase in computers in use since they were first placed on the market for general commercial use in 1955.

A further indication of the rapid growth in the use of computers and the applications to which they are put is that in January 1960, Computers and Automation published the results of a survey of electronic data processing equipments manufactured by United States equipment makers and their application. The survey revealed that digital computers were being used in 310 different areas of application, and over half of these were business uses. The survey also reported that there were a total of 20 models of computers produced by United States manufacturers on the market.[9] In June 1961, only 18 months later, the number of applications had increased to over 500, and the number of models on the market had

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[8]Robert M. Smith, "Automation Revolution Will Effect Every Phase of U. S. Economy," Office Management and American Business, XXII No. 1, (January 1961), pp. 8, 9.

[9]Computers and Automation, Vol. 11 No. 1, (January 1960). pp. 13-15, 20-22.

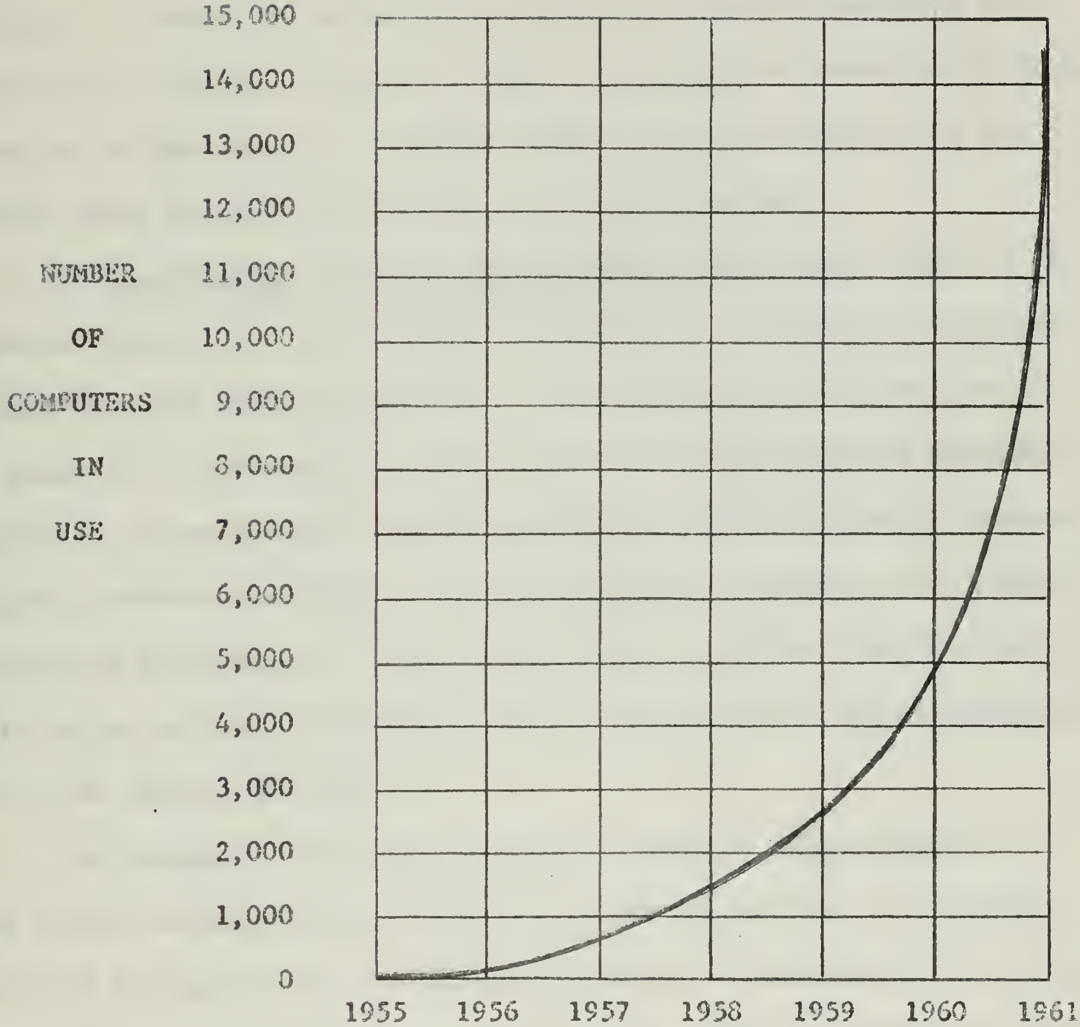


FIGURE I

NUMBER OF COMPUTERS IN USE IN THE UNITED STATES 1955-1961

increased to 62.[10] An indication of the future growth of the computer is the fact that the industry as a whole had gross sales in excess of one billion dollars in 1961, and it is predicted that sales will double, then redouble in the next four to seven years.[11]

As mentioned earlier there are over 500 applications for computers. Obviously, it would be impractical to list all uses of computers in a paper of this nature. However, to give the reader an appreciation of the potential of the computer, the major general applications with a few specific uses are discussed in the following paragraphs.

1. Repetitious clerical and accounting paper work. This is the bread and butter use of the computer because of its ability to rapidly perform repeated routine operations. All industries have made use of the computer in performing routine clerical, bookkeeping and accounting functions. These include payroll computation, sales analysis, inventory control, accounts receivable, accounts payable, production cost control and similar operations. In fact, most large companies today have multiple installations of computers with at least one of them devoted entirely to the payroll functions.

For example: Ford Motor Company is using a large computer to save several hundred thousand dollars a year in the cost of preparing their 100,000 men payroll in the Detroit area.[12] The payroll accounting not only produces checks, but it also computes federal, state and local

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[10]Computers and Automation, Vol. 10 No. 6, (June 1961). p. 99-113, 133-137.

[11]"Hot Race for Far-off Profits," Business Week, No. 1700, (March 31, 1962), p. 62.

[12]E. Wainright Martin Jr., Electronic Data Processing, An Introduction (Homewood: Richard D. Irwin, Inc., 1961) p. 3.

taxes, labor union dues, social security, savings bonds, credit unions, retirement plans and similar related functions.

All the major life insurance companies generate large volumes of paper work. Accordingly, they have installed large computers to perform such functions as premium billing, commission accounting, dividend calculations, reserve calculations, actuarial calculations and other similar operations. Many of the insurance companies report large savings. One company reported that the computer installation replaced 113 people and a punched card accounting system costing about $216,000 a year.[13] The versatility of the computer is demonstrated by the fact that computers enabled the New York Life Insurance Company to replace in less than one month a file of 250,000 policy cards destroyed by a fire on November 18, 1960. The information on the cards was duplicated on magnetic tape at the home office. A high speed printer took the data off the tape in three days and cards, with at least 20 items of information, were reproduced in three weeks. The company estimated the job would have taken nearly a year to accomplish by pre-automation methods.[14]

Continental Casuality Insurance Company Vice-President Walter Foody advises "The computers enable us to launch massive nationwide sales campaigns - writing as many as 30,000 policies in a single day - that

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[13] K. G. Van Auken, Jr., "The Introduction of an Electronic Computer in a Large Insurance Company," Automation and Technological Change, (Hearing before the Subcommittee on the Economic Stabilization of the Joint Committee in the Economic Report 84th Congress, 1st Session), (Washington, D. C., 1955), pp. 290-300.

[14] News Item in the Wall Street Journal, December 19, 1961.

simply would not be possible without them."[15]

Banks have found the real time computer an economical investment. A typical real time system installed by one of the largest mutual savings banks in the United States includes a central computer which will simultaneously control transactions at each teller's window in each of the bank's five branches. Each teller has a "tellers set" about the size of a typewriter. When the customer comes up to the window, the teller inserts the customer's pass book in a slot in the "tellers set" and types in the transaction. The computer instantly updates the customer's account and transmits the information back to the bank teller. It enters the transaction in the passbook and also enters all interest accumulated since the customer's last visit to the bank. Also, in a matter of milliseconds, the computer can perform mortgage accounting, payroll processing, life insurance notices, personnel records, Christmas Club accounts, customer loan accounts, and other bank functions. The bank purchased the computer system for $2,000,000, and estimates that savings in operating expenses will pay for the computer and also give the bank a savings of $1,830,000 in ten years.[16]

Large hospital service organizations and hospitalization insurance companies employ computers for their complete operation including daily billing, payment of hospital and doctors' bills, determination of enrollment eligibility for thousands of prospective customers, maintaining customers accounts, and all kinds of statistical analysis.[17] Computers

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[15]"Business in 1961," Time Magazine, LXXVIII No. 26, (December 29, 1961), p. 51.

[16]"Savings Bank Automation with Real Time Computers," Data Processing, Vol. 3 No. 12, (December 1961), pp. 27-29.

[17]Honeywell Advertisement, Fortune Magazine, LXV No. 1, (January 1962), pp. 162-163.

of the type used in these applications can update 200,000 individual records in just seventeen minutes, complete a 10,000 man payroll in less than two hours, or sort 10,000 fifty character items in four minutes.[18]

Most universities and colleges, no matter how small, have computer installations. These computers are usually used for classroom instruction in electronic data processing and scientific problem solving, calculating research projects and in administrative data processing. In the latter application, real time allows an up to the minute computation of the students enrolled in specific courses, so that over-enrollment is precluded during registration. They are also used to schedule courses, maintain students' records, mark papers, compute grades and averages, bill students for various charges and perform the normal housekeeping functions of payroll, cost control, budgets and similar jobs.

Another important use of computers in industry is for personnel records. These records are usually broken down into four categories: selection and placement, classification and analysis, welfare and morale, and individual history record. All data required by these categories is entered in the computer. Then, in a minute's time, it is possible to have complete listing of all company personnel that are eligible for a promotion, have completed a certain course, have not had an accident, have not been tardy, have been employed for ten years, and other qualifications. The advantages and the savings are quite obvious.

Industry has also found it to its advantage to use data processing and the computer for plant and equipment accounting. A complete history is maintained of all equipment from the time of its acquisition until it

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[18]Honeywell Advertisement, Business Week, No. 1696, (March 3, 1962), p. 11.

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[18]Honeywell Advertisement, Business Week, No. 1696, (March 3, 1962), p. 11.

is retired. This information will include costs, depreciation, transfers, maintenance, emergency repairs, usage and other similar statistics. This provides management with accurate cost controls and statistical information on which to base decisions relating to the procurement, use and retirement of capital equipment.

A typical small computer for routine sales and accounting work in a small firm will prepare the sales order, produce the work order, shipment order, bills of lading and shipping memorandums. Upon shipment it will then update the inventory and if this shipment reduces the inventory to a prescribed level, it will write a purchase order for replacement, prepare voucher checks, receiving reports, accounts payable records and purchase commitment analysis. When the material is shipped to the customer, the computer computes and writes an invoice, prepares an accounts receivable register and other statistical reports. Upon receipt of payment or material it again updates all records to reflect actual status of inventory and accounts.[19]

The transportation industries are quickly learning the value of computers. In addition to regular payroll, billing and accounting procedures, the computers are used to figure tariff rates for different commodities, adjust rates as necessary, compute the most equitable rates and most profitable loads. Union Pacific Railroad uses a computer in this fashion and also to automatically route freight at electronic classification yards and to keep track of all freight cars loaded and empty.[20]

2. Large storage of information. The computer's ability to store

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[19]Friden Advertisement, Fortune Magazine, LXV No. 1, (January 1962), p. 122.

[20]Union Pacific Railroad Advertisement, Business Week, No. 1698, (March 17, 1962), pp. 44-45.

large amounts of information and to provide fast access to such stored information makes it very useful for reservation systems for large hotel chains, airlines, and other activities having a requirement to store large quantities of information, yet be able to provide instant replies to inquiries.

Most large airlines have, or are installing, world-wide electronic reservation systems consisting of remote units connected to a central computer. Under this system any agent throughout the world can query a computer on space availability for any flight, and receive an answer in less than five seconds. He can then make the reservation in less than one second. This same system will also compute or verify complex routings in less than five minutes. The same computer system also does housekeeping chores for the airline, such as routine accounting, payroll, and inventory of aircraft repair parts.

An information retrieval system is an arrangement of microfilm cameras, computers and mechanical selection devices designed to reduce the information in business, government and academic libraries to manageable bulk, index it thoroughly, search through it on command for wanted information and produce it in a matter of minutes. International Business Machines estimates that companies, professional groups and universities are spending twenty million dollars a year in information retrieval equipment, and that system sales will mushroom to five hundred million by 1971.[21] In a typical system, the computer indexes the contents of a library by feeding titles into it and having it pick out key words under which to list them. Then the computer can be queried by using key words, and a listing or a copy of all documents indexed under that key word will be

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[21]Norman C. Miller, Jr., Wall Street Journal, December 11, 1961.

printed out. A system designed to handle microfilmed copies of ninety-nine million odd reports, books, newspapers and maps will be delivered to the Central Intelligence Agency in 1962.

3. Data Reduction. The ability of the computer to rapidly absorb large amounts of information, classify it into various categories and produce summaries has opened up new vistas to statistical analysis in many areas. While man has always seen the need for compiling vital statistics in such areas as science, medicine and criminology, he has been thwarted by the time and money that would be involved in accomplishing the analysis. Today the computer does the job in a matter of minutes.

The Secret Service is using computers to assist them in its battle against check forgers. Each forgery discovered is entered into a computer where it is compared with prior forgeries. Various details of the forgery are matched with details of prior forgeries, which often leads to the forger. Mr. James L. Lewis, special agent in charge of the Service's forgery section considers the computer "our only solution" in tracking down multiple forgers. He said that "We're getting 40,000 forgeries a year and we just can't keep them all in our memories."[22]

Most of the large stock brokerage offices are using computers to maintain latest prices of stocks, customers' accounts and transactions. Stock prices are automatically fed to the computer from the ticker tape. The computer then stores the various prices including opening, high, low and last price. Any branch office can query the computer and get the prices desired instantly. Mr. Michael McCarthy, Chairman of Merrill, Lynch, Pierce, Fenner & Smith, which handles eighteen percent of the shares traded on the New York Stock Exchange said, "It would be almost impossible

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[22]News Item in the Washington Post, March 11, 1962.

for us to handle our present volume without computers."[23]

Newspapers use computers to automatically accumulate stock prices. When an edition goes to press, the computer prints out a listing of all stocks traded, their volume of sales and prices, all in less than a minute. Newspapers also use computers to assemble their classified advertisements and to do the billing and accounting. When a request to run a classified advertisement is received, complete information is punched in a tape and entered into the computer. When it is time for the paper to go to press, the computer prints out all the classified advertisements alphabetically, under the proper heading. It keeps a record of the number of days each is to run, drops it on the prescribed day, automatically prints the billing, and maintains the customer's account until payment is received and the account is closed.

Pratt and Whitney Aircraft has 12,000 production machines built by four hundred different manufacturers. In order to reduce and control maintenance costs, all preventive maintenance requirements and routine maintenance tests were placed in a computer. The computer now schedules over 18,000 maintenance operations in these plants. The computer also maintains a complete maintenance history of each machine including down time, repair costs and description of work done. Statistical reports, backlogs, employee records, and other similar statistics related to maintenance can be produced as desired. In the three year period since maintenance was scheduled by computer the following results have accrued:

a) Increased efficiency of machine repair department by 40%.

b) Reduced unscheduled or emergency calls by 25%.

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[23]"Business in 1961," Time Magazine, LXXVIII No. 26, (December 29, 1961), p. 50.

c) Increased productivity of lubrication personnel by 35%.

d) Reduced maintenance hours per year on a battery of tracer controlled units from 1,879 to 243; reduced number of repair calls by 72%.[24]

4. Simulation. Many problems in industry today are too complex to solve even with a computer. The only solution to the problem lies in the trial and error method. However, the trial may be very expensive and the resulting error even more costly. These costs can be saved by simulation techniques employing the computer. In simulation, a real world system or situation is reproduced, or duplicated, in mathematical symbols. This model may be an entire transportation system, a complete production process or an assembly line. After the model is completed and programmed into the computer, trial and error experiments can be conducted and the results observed. The speed of the computer will permit it to simulate a years production in less than twenty four hours of computer time. By simulating all possible occurrences it can be determined which factors affect the different portions of the model. These results will then influence future decisions.

Matson Navigation Company has constructed a complete model of its passenger and cargo service between west coast United States ports and the Hawaiian Islands. By simulation they have run many years of this service under various conditions. As a result, they have determined what types ships to employ, the best routing, how to handle loss of cargo caused by labor strikes, and other uncertainties. The model is specifically used for:

1) Optimizing schedules.

2) Evaluating new ship types before the company buys them.

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[24] Mobil Oil Company Advertisement, Fortune Magazine, LXIV No. 6, (November 1961), pp. 30-31.

3) Optimizing fleet composition.

4) Pricing new services.

5) Evaluating labor practices.

6) Developing logical tariff structure.

7) Predicting results of changes in tonnage shipped by customers.

8) Predicting how to optimize schedules in face of shipping strikes, sugar strikes and changes in competitive services.

Although innumerable results have been obtained, one concrete result of this program is the fact that since this program was started five years ago, Matson has reduced its fleet from fifteen ships to twelve ships, but they are carrying 20% more revenue tonnage.[25]

Seven American and Canadian railroads are financing a one million dollar three year study by Battelle Memorial Institute of Columbus, Ohio designed to tell the industry how to run a better railroad. Battelle systems engineers will build a complete mathematical model of the railroad freight system and using a digital computer will test the results of all possible factors of operations. The railroads hope to improve their operating efficiency by determining such factors as how to distribute freight cars, how many switch engines should be used, how to handle empty cars, and other similar factors.

5. Automation. In many industries the computer, in conjunction with a control loop and a feed back loop, controls entire processes, assembly lines or the entire factory itself. Oil refineries were the first plants to be automated. Chemicals followed closely behind, and now we find most manufacturing processes automated to some extent.

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[25]Foster Weldon, "Simulation of Fleet Operations," Lecture, NPGS Monterey, February 2, 1962.

[26]News Item in the Wall Street Journal, March 2, 1962.

One of the first computer controlled factories was the Texaco Polymerization Plant at Port Arthur, Texas. In this plant, a special purpose digital computer receives information (feed back) from 110 sources and controls 16 flows, pressures and temperatures. Since the plant was already instrumented, a large saving in personnel costs was not experienced, but the computer was more efficient and increased production from 87% to 93%.[27]

Corn Products Company, manufacturer of Knorr soups has automated its huge Argo, Illinois five story plant with a computer like brain. There is a wired board for each soup recipe. This board is placed in the computer, which controls the process with the help of nine mixing control stations, which receive signals from the computer. Workmen just monitor the operations with all data being recorded by machine. If something goes wrong in the complex process, lights flash on and the computer stops all production.[28]

One of the latest and most sophisticated uses of the computer is in numerically controlled N/C milling machines which produce complex parts, without human intervention, from a series of numbers representing mathematical coordinates of the surfaces involved.[29] Machines guided by N/C can now do jobs that were never feasible before because of human inaccuracy and fatigue. They can do any job more precisely, at higher speeds and with less waste of material.

N/C is in its infancy with 50% of the units on factory floors having

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[27]"Computer Runs Refinery for Texaco," Business Week, April 4, 1959, pp. 44-54.

[28]George Bookman, "The Uncommon Market of Corn Products," Fortune Magazine, LXV No. 3, (March 1962), p. 99.

[29]"Making a Machine Run Itself," Business Week, March 9, 1957, No. 1436, pp. 183-187.

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been installed in 1961. It has been stated, however, that without N/C it would not have been possible for the United States to advance in the aero space and missile field as it did. In fact, the Air Force is favoring contractors with N/C equipment to speed contract fulfillment and product precision. Largely confined to the missile and air frame industry in its early stages, N/C is now spreading to all industries. The testimonials of firms using N/C are endless. A few are reported from a recent article in Fortune.[30] For example: Miehle-Gross-Dexter reports that N/C cuts 10 to 40 percent off the cost of making certain graphic-arts equipment parts; Boeing saves 40 percent on templates it makes with N/C; Pratt & Whitney estimates that N/C saves it 70 percent of the cost of making certain parts with close hole tolerances.

It is predicted and quite reasonably so, when the savings already registered by N/C are noted, it will revolutionize the machine tool industry in the next five years.

The computer has also proved invaluable in scheduling projects or production using program evaluation and review techniques (PERT) or the similar critical path method (CPM). Under this technique, a complete program is broken down into individual tasks. Each task is then evaluated and it is determined how long it would take and what it would cost to perform each task in minimum time, normal time, and at minimum costs. This system also determines the critical path, or the sequence of individual tasks, which limits the time to complete the project. This whole problem is programmed into the computer and keeps management apprised of the status of all tasks, current costs, estimated future costs and estimated date of completion. PERT has been credited as the major contributing factor in

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[30]Herbert Solow, "How to Talk to Machine Tools," Fortune Magazine, LXV No. 3, (March 1962), pp. 120-124.

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the completion of the Polaris missile two years ahead of schedule.[31]

6. Problem Solving. Computers were specifically designed to solve scientific, mathematical and engineering problems. Some of the problems they solve are not complex, but they are so long and so cumbersome that it is just impractical to solve them without a computer. A good example is the determination of prime numbers. This computation requires up to 50,000 operations to find one number, but the new computers can find several thousand primes in an hour. Other simple problems are those involving many variables which couldn't be computed by hand but can be done by a computer in minutes.

The computer is also invaluable in solving many complex mathematical and scientific problems which man was just incapable of physically solving before the computer was invented. It is invaluable in the missile and aircraft industry, and it has been said that without them, supersonic flight and space flight would still be a dream. In these industries the computer is used to design the hardware, and the final product. Considering the money and time invested in our latest missiles and aircraft and the problem of personnel safety, the United States wouldn't dare launch a missile or allow an aircraft to take off unless it were sure it could fly. The computer gives this assurance.

The rapid development of nuclear capability has also depended on the use of the computer in problem solving and guiding the engineer's design, plans and decisions from beginning to end. Reactors themselves are monitored by computers to ensure safe operation, optimum efficiency, immediate recognition of trouble, and instituting immediate corrections.

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[31]George A. W. Boehm, "Helping the Executive Make Up His Mind," Fortune Magazine, LXV No. 4, (April 1962), p. 130.

7. Operations research and decision making. Operations research, frequently referred to as quantitative decision making, operations analysis, or management science is a new science which is closely related to and relies heavily upon the computer. Operations research refers to the scientific method and advanced mathematical and statistical techniques used in management decision problems. Basically, operations research provides techniques for determining various alternatives or courses of action, assigning values, utility measure, or penalties to these alternatives, and then helping the manager optimize the objective function. Unfortunately, most of the problems which are solved by operations research techniques contain so many variables and parameters that solution by man is impractical. However, the computer can solve most of these problems in a matter of minutes. To emphasize this point it is only necessary to note that a million multiplications performed by a human using a desk calculator would take about five years and cost about $25,000. The same task performed by the earlier computers would take eight minutes and cost about $10.00, while the new LARC computer would perform these multiplications in eight seconds at a cost of fifty cents.[32] Operations research teamed with the computer make a potent management tool which has revolutionized the process of decision making.

8. Special applications. Computers of special design are used in many specialized applications. Some important uses are in the guidance and control of missiles, satellites, and space vehicles. They are also used to receive analysis and correlate radio telemetry signals from these vehicles. Aircraft are also equipped with small computers and

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[32] A. S. Householder, "Solving Problems with Digital Computers," Computers and Automation, Vol. 5, No. 7, (July 1956), p. 6.

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wherever speed and technology are increasing computers are being installed.

9. The future. The future of the computer and electronic data processing in unlimited. Each day they are being applied to new uses and each day the computer and associated equipments are being improved. Some of the latest applications in industry, many of which are still in the development stage, are listed below. While some of these uses are considered facetious, it is obvious that the techniques employed will find utilization in other methods in industry.

International Business Machines has programmed a computer to play checkers with a human. To make sure it wins, the machine is programmed so that before each move it tests all possible moves and all possible succeeding moves for two turns, and then determines the best move.[33]

Another computer has been programmed to answer billions of baseball questions providing they are precise and asked in a two-hundred word vocabulary. Another has been programmed to translate foreign languages and still another to compose simple melodies.[34]

A Univac 1 computer has been programmed to play bridge. It deals four hands randomly, then proceeds to bid one or more of the hands for one round of bidding. The hands of the other players are typed out for them to see, and when it is their turn to bid, their bid is typed into the computer.[35]

While it is generally thought that a computer can not learn, much

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[33]John Pfeiffer, "Problems, Too Have Problems," Fortune Magazine, LXIV No. 4, (October 1961), p. 145.

[34]Ibid. p. 168.

[35]Thomas A. Throup, "Univac Plays Bridge," Computers and Automation, Vol. 11 No. 3, (March 1962), p. 3B.

effort is being devoted in this area.[36] A program called the "Logic Theorist" has been written in an attempt to prove theorems in mathematical logic by simulating processes similar to those used by humans. Using this programming, a computer was able to discover proofs of 38 of the first 52 theorems in Principia Mathematica, a highly regarded mathematical book. In fact, in one instance, the computer proved one of the theorems in a more concise method than man had been able to do. Much experimentation is going forward in this field and encouraging results have been achieved.

Pennsylvania Power and Light Company is installing an optical reader in conjunction with its computer.[37] The machine will "read" conventional printed or typed information somewhat like the human eye and write the results on magnetic tape. This tape is then used as in input to the computer. Thus the electronic data processing system will receive the raw sheets on which the meter readings are recorded, enter the readings in the computer and compute the customer's bill. The machine will have a capability of processing 22,000 bills a day.

The Itek Corporation of Lexington, Massachusetts has developed a photoelectric light pen with which an engineer formulates his problem by graphically drawing it on a console that looks like a flat television screen. The design passes into the computer which solves the problem and stores it in memory. This saves the timely conversion of engineering drawings into mathematical formulas.[38]

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[36] H. A. Simon and A. Newell, "Heuristic Problem Solving: The Next Advance in Operations Research," Operations Research Journal, January, February 1958. p. 1.

[37] "Optical Character Reading into Computer Equipment," Computers and Automation, XI No. 3, (March 1962), p. 10B.

[38] "Technology," Time Magazine, LXXIX No. 9, (March 2, 1962), p. 74.

In a recent article in Operations Research ideas were presented on the utilization of computers in medical data processing. Under the proposed system, the computer could compile statistics relating symptom-disease combinations, retrieve current information about new preventative measures, diagnostic techniques and treatments, produce lists of medically consistent diagnoses possible for a given set of symptoms, indicate what future diagnostic tests should be made, calculate the probabilities and compile or recall desired aspects of a particular medical history. The system visualizes an area computer available to hospitals and physicians which is linked real time to a large research center computer.[39]

## IV. MILITARY USES

The Department of Defense has been a forerunner in the EDP revolution and must be given much credit for the development of the art. Recall that it was the military which sponsored the Harvard Mark I and the ENIAC in order to have a method of rapidly solving the trajectory problem. The advent of jet aircraft and missiles flying at speeds many times the speed of sound have forced the Department of Defense to develop methods that will process data instantaneously, so that military decisions can be made in time to intercept these weapons. It has also been necessary to design small electronic computers to control and guide the military's high speed aircraft and missiles. Thus the Department of Defense has been a leader in the computer crusade and must be credited with encouraging the technological revolution in EDP.

The Defense Department is also the biggest user of computers. In

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[39]Robert S. Ledley and Lee B. Lusted, "Computers in Medical Data Processing," Operations Research, Vol. 8, No. 3, (May-June 1960), pp. 299-310.

1960, 218 installations utilized 360 computers and in 1961 the quantity increased to 493 computers in 298 installations. Under current plans this will grow to 661 computers in 375 installations in 1962.[40] If present trends continue the Department of Defense will exceed this amount in 1962 and in two years time the number of computers in the Department will have doubled.

The Navy has made strong efforts to control the rapid rise in EDP within this service and thus ensure maximum utilization of each computer installed. The Secretary of the Navy issued SECNAV Instruction P10462.7 on 16 April 1959. This instruction entitled, "Navy Data Processing," cancelled all previous instructions on this subject and consolidated "general objectives, organizational responsibilities, procedures, criteria, policies and guidance for the technical advancement and effective, efficient, and economical utilization of punched card, electronic and associated data processing equipment card techniques in Navy Marine Corps logistics and business administration."

This instruction divides the Navy policy on ADP progress into six, five year stages, as follows:

Stage 1 (1940-45) - Development of the first computers for high speed mathematical calculations.

Stage 2 (1945-50) - Modification of scientific computers to perform business data processing.

Stage 3 (1950-55) - Recognition of the vast potential of electronics to process "paperwork" and improve information systems.

Stage 4 (1955-60) - Initial acquisition in quantity of feasibly

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[40]C. W. Borklund, "What's Ahead for Defense ADP," <u>Armed Forces Management</u>, Vol. 7, No. 10, (July 1961), p. 19.

useful "first generation" electronic equipment for data processing and the development of source data automation, communications, and management sciences adjuncts to computers.

Stage 5 (1960-65) - Completion of evaluations of early applications; shifting of program emphasis from recording, storing, processing, to forecasting, planning, programming; the evolution of improved hardware, and an orderly transition to a full complement of adult equipment.

Stage 6 (1965-70) - Navy-wide perfection of the best ways and means for management to use advanced hardware and personnel to achieve an Integrated Navy Management Information System.

Administrative Systems. The Marine Corps EDP program has developed around two electronic computer systems, a Material Management System and a Personnel Management System.[41] Wherever installed, computers for these systems also perform housekeeping functions such as fiscal accounting, cost accounting, disbursing, and similar functional requirements. The Marine Corps total system makes use of both mobile and fixed installations and has as its primary objective to provide the best possible information on resources to decision makers in order to enhance the effectiveness of the Marine Corps. Secondary objectives include reduction of administrative burdens at all echelons, maintenance of complete, timely and accurate files, maintenance of alternate files adequate for use in event of destruction of central files, and improvement of mobilization capability.

The Bureau of Naval Weapons is engaged in testing and evaluating a project known as the Refined Aeronautical Support Program (RASP) designed to improve the material support of fleet units through high

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[41] Navy Management Review, V No. 10, (October 1960), p. 11.

speed logistics data communications, improve scheduling and reduction of material in the pipelines.[42] Pilot installations of computers are in operation at the Naval Air Station, North Island, California, and the Naval Air Station, Alameda, California. The Naval Ammunition Depot, Concord, California is evaluating prototype electronic data processing systems for ordnance activities.

The Bureau of Supplies and Accounts is planning to install a Uniform Stock Point System computer network between fourteen supply stock points ranging from Yokosuka, Japan to Newport, Rhode Island. Under this system, when a ship requests material that is not available locally, the whole supply network is instantaneously queried as to whether the material is available. If it is available at another activity, and the priority warrants it, immediate shipment can be effected. The computers at each activity will be programmed to do all the necessary data processing including inventory control, receipt control, issue control, appropriation accounting, material movement, payroll, cost accounting and even print the parcel post address labels for affixing to the package for shipment.

The Navy Finance Center located at Cleveland, Ohio has installed a computer to handle 1,000,000 allotment accounts, 100,000 retired pay accounts and 1,700,000 pay records. Using the new equipment, records will be updated daily instead of monthly, will reduce processing time, will give more accurate results and allow retired and retainer pay checks to be issued in one fifth of the man hours required when utilizing conventional EAM equipment.[43]

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[42] Ibid., p. 15.

[43] Armed Forces Management, Vol. 7 No. 4, (January 1961), p. 45.

The Bureau of Naval Personnel's Naval Manpower Information System will consist of major data processing systems at San Diego, California, Pensacola, Florida and Norfolk, Virginia, all linked to a computer in Washington, D. C.[44] One station will serve all the Atlantic Fleet, one will serve the Pacific Fleet and one will serve the continental United States. These stations will collect, maintain and process over sixty items of information for each enlisted person and about two hundred items for each officer. The goals of the Bureau of Naval Personnel's System are to achieve better and longer range advance training, faster distribution of personnel, reduction of the number of people in transit between assignments, better coordination among commands, the better fitting of a man to a job, greater personal attention to individual needs and thus higher morale and a stronger fleet.

While the Navy is installing several logistic and administrative computer networks, the Air Force is installing one network called the Command Logistic Network (COMLOGNET) that will connect 350 air bases, depots and stations around the country and control the flow of men and material throughout the Air Force.[45] This is one of the largest data processing systems and has the capacity to handle seven million punched card requisitions and more than 100,000,000 words daily with each message being processed automatically on a security and priority basis.

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[44]Navy Management Review, Vol. V No. 10, (October 1960), p. 20.

[45]Air Force Combat Logistics Network to Handle 100 Million Words Daily," Computers and Automation, Vol. 11 No. 1, (January 1962), p. 29.

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Tactical Systems. One of the most sophisticated military computer systems in use today is the Navy Tactical Data System (NTDS).[46] This system consisting of communications, data processing and display, will weld an entire task force into a single defensive unit and will provide the task force commander with a schematic picture showing the enemy targets, their type and movements, the defensive and offensive position of friendly ships and recommendations for action. When the Commander makes his decision - either the one recommended by NTDS or his own - the system transmits the appropriate orders to the ship's fire control equipment or to the aircraft that will make the attack. This equipment is scheduled to be installed on every major ship of the fleet from DLG up. NTDS will solve the impossible human task of coping with anticipated simultaneous assaults of missiles and aircraft flying at thousands of miles an hour, and submarines. Active information coming from radars, sonars, radio, Iff, electronic countermeasure systems and human sources go into moduler designed data processing equipment on each ship. Here the identity, size, location, course and speed of both friendly and enemy vehicles are determined. This information will also be automatically exchanged by communication link from the computer on one ship to the computer on another ship. Thereby, all ships are kept constantly informed of all other ships' information.

Administrative and logistic programs are now being written for the AN/USQ 20 computer, which is the heart of the NTDS system,

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[46]John F. Mason, "Navy's Sage for the Fleet Opens Market, Electronics, Vol. 33 No. 38, (September 16, 1960), pp. 30, 31.

by personnel attached to the Fleet Computer Programming Center, Pacific at San Diego, California. The writer witnessed the processing of an entire quarter's commissary transactions of a DLG including the computation of a quarterly balance sheet in a matter of minutes utilizing the AN/USQ 20. The computer has been operating in parallel with manual data processing on the ships. As expected, the computer has proved more accurate than the ship, and many times has found errors in input data and computations.

The Air Force has several tactical data systems, one of the largest of which is the complex SAGE air defense system.[47] The computer for this system is an extremely large one into which is fed the flight plans of all aircraft scheduled to fly in the vicinity of the defense system, reports from observers, weather reports and radar observations. When an aircraft is detected, its position, course and speed are compared with all stored plans to determine if it is a scheduled flight. If not, the target is transferred to a sector control officer's radar scope and the plane is tracked until it is intercepted. In the event of many targets appearing at once, the computer directs the interceptors to the target.

The Army is also testing and evaluating five BASICPAC tactical field computers and a large scale MOBIDIC computer.[48] These

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[47] H. T. Rowe, "The IBM Computer AN/FSQ 7 and the Electronic Air Defense System SAGE," Computers and Automation, Vol 5 No. 9 (September 1956), p. 6.

[48] "BASICPAC Tactical Field Computer," Philco Corporation Information Manual. Stanley K. Choo, "The System Organization of MOBIDIC B," Proceedings of Eastern Joint Computer Conference, December 1-3, 1959, p. 101.

equipments are medium and large size respectively and are housed in shelters that can be transported on a two and one half ton truck or are installed in thirty foot trailers. The computers are capable of being linked into a network and used for weapon target allocations, loading plans, march tables, estimates of weather and fall out patterns, and reallocation of radio frequencies in the event of enemy jamming. They also perform administrative data processing including payroll, general file maintenance, matrix calculations, data reduction, linear programming, statistical analysis, complex equations, weapons system analysis and operations research.

War Gaming and Simulation. All services employ war gaming and simulation techniques utilizing computers as training devices and to determine best possible courses of action under varying circumstances. The Army, for example, has built a complete model for determination of transportation of service troops and also the equipment required under various plans to reduce time and effort for such planning, to improve the quality of output and gain the capability to vary assumptions, and to consider alternative courses of action.[49] A typical Air Force game is SAFE, a strategic air-war planning game concerned with force composition,

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[49]Martin W. Brossman and others, Computer-Assisted Strategic Logistic Planning, Transportation Phase-ORO T393, Operations Research Office, John Hopkins University.

procurement strategy, deployment and operational strategy for an air war.[50] The game is used for instructional purposes at the U. S. Air Force Academy and covers a simulated nine year period, however, the computer compresses this time into five eight hour days of game time. The Navy has comparable models including a Ship-to-Shore Model, the Embarkation Model and the recently developed Reembarkation Model.[51] There are many other models available and more will be created as the need arises.

## V. A WORD OF CAUTION

All electronic data processing systems have not met with the resounding success of the applications just discussed. There have been some miserable failures and they were expensive failures. However, these failures were caused by man and not the computers themselves. Some activities have procured computers just to "keep up with the Jones". Other activities have procured computers without a thorough system analysis and redesign of procedures to best utilize electronic data processing. Some managers installed computers without conditioning the employees, and the latter made it their business to ensure that the computer couldn't

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[50] Olaf Helner and R. E. Bickner, "How to Play SAFE-Book of Rules of the Strategy and Force Evaluation Core," RM 2856-PR, (Rand Corporation), November 1961.

[51] Paul G. Mode, Jr., "The Reembarkation Model," Technical Memorandum K 32/61, U. S. Naval Weapons Laboratory, Dahlgren, Virginia.

do the job. It must be concluded from these failures that before installing an electronic data processing system, a careful system analysis must be performed to ensure that a computer will do the data processing economically, procedures must be redesigned as necessary, a computer must be selected that will best perform the requirements of the activity and personnel must be thoroughly conditioned. Mr. M. E. Salveson summed this up when he said:

> Typically, the failures (of computers) have not been due to inadequate or defective equipment. Rather they have been from inadequate preparation, insufficient understanding, or lack of participation by all levels of management.[52]

## VI. SUMMARY

Computers are reaching like an octopus into every facet of our lives. While people may marvel at the many jobs which a computer has been able to perform, this is just the beginning or as Martin H. Weik describes it, "the seed is about to sprout!"[53] The computer industry is still in its infancy and while the military is ahead of civilian industries in operational use of computers, it seriously lags civilian industry in electronic data processing. Accordingly, the military services must be prepared

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[52] M. E. Solveson, "Electronic Computers in Business," The Journal of Industrial Engineering, March-April 1958, p. 104.

[53] Martin H. Weik, "Computers: Impact 1962," Data Processing, Vol. 4 No. 4, (April 1962), p. 33.

to exploit the use of computers to the fullest extent in the near future.

# CHAPTER III

## HOW EDP CAN BE USED AFLOAT

The federal government was one of the first activities to adopt electronic data processing and today is one of the biggest users of computers. Over two-thirds of these computers are being used by the Department of Defense, making the latter the largest single user of computers.

The purpose of the discussions of the use of electronic data processing in industry in the preceding chapter was to give the reader an insight into how the electronic computer could be used and then apply some of these techniques to similar systems in the military. However, it must be remembered that electronic data processing is in its infancy and that the surface has just been scratched in using it to assist man in his daily work. Therefore, a conscientious effort must be made in all planning to make as many routine jobs as possible subject to EDP.

### I. TOTAL SYSTEM CONCEPT

The question to be answered in this chapter is how EDP could be used afloat. While the primary aim of this paper is to determine if EDP is feasible to handle the bulk of the paperwork of the Supply Department, it soon become evident that in installing a computer aboard ship for data processing, it must be made available to all departments. Consequently,

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a discussion of how EDP could be used afloat must be based on a total system concept. That is, the entire shipboard data processing system must be integrated wherever possible to eliminate overlap and duplication leading to wasted effort.

A good example of duplicate data processing is in the case of a man reporting aboard ship. Notice the paperwork that this common occurrence generates.

1) He reports to the personnel office for processing.

2) He reports to the Chief Master At Arms for processing.

3) He reports to the Medical Officer for processing.

4) He reports to the Dental Officer for processing.

5) He reports to the Disbursing Officer for processing.

6) He reports to the officer responsible for the maintenance of the Watch Quarter and Station Bill.

7) He reports to the Training Officer for processing.

8) He reports to the officer responsible for maintenance of the Battle Bill.

9) He reports to the Division Officer for processing.

Under the integrated procedures, the man would report to one place, the Personnel Office. Here a card would be made out with all the necessary information contained therein. The card would be used to punch a paper tape for input into the computer. The man would be assigned his battle station, billet number, bunk number, division cleaning station, liberty section, watch section, etc. by the program in

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the computer. All ship's records affected by the reporting aboard of the man would be corrected instantaneously. They would always be current. The computer would print out the necessary information about the man and this would be forwarded to the appropriate officers for information or action. It is quite obvious from this example, and many other similar situations, that shipboard data processing must cut across all organizational lines. It must be integrated, and it must be designed on a total system concept.

## II. NAVY WIDE CONCEPT

Just as the total system concept should be considered to include all data processing within the command, the total system concept should also include all data processing within the Navy or Department of Defense as a whole. With the installation of the NTDS aboard ships and the technological advancements in communications, it is reasonable to expect that in a short time, computers will be talking to each other and reports or requirements will be submitted by these communication links. As was noted in Chapter II, most bureaus and shore activities are installing computer networks. Possibly due to oversight or economic reasons, ships have been omitted from the total Navy system concept. It is absurd, however, to permit ships' personnel to continue to prepare the ship's requirements and reports by adding machine and typewriter,

then deliver this information to shore activities where dozens of clerks would be required to transfer the data to computer input format. This is not only costly but it increases processing time and introduces errors into the process. It is comparable to pulling a 1962 Cadillac with a horse. In planning the shipboard system it must be anticipated that the output will be taken from the ship's computer and transferred directly to a shore based computer by communications link or by mailing a machineable format. Personal contact should be eliminated wherever possible to prevent the build up of a backlog at any point in the cycle, and also to prevent any delay in the processing of requirements or reports. The concept should envision "womb to tomb" data processing.

## III. SYSTEMS ANALYSIS

In adapting the shipboard workload to data processing, the current system in use may be initially adapted to electronic data processing. However, as soon as practical a complete analysis of the system and procedures must be made with a view toward changing the entire system so that it is more susceptible to efficient EDP. It should be the declared purpose of this analysis to revamp the shipboard systems, procedures and organization as necessary. As Mr. J. L. Powell of the Office of the Secretary of Defense pointed out in a recent speech "if a computer is installed at an activity

without a complete system analysis, the present red tape just becomes instant red tape."[54] At the same time, due consideration must be given to "audit trails". Care should be taken to insure, however, that the auditing problem is not used as an excuse to preclude the reorienting of shipboard data processing and organization to EDP.

## IV. COMPONENTS

The basic components of a shipboard electronic data processing system should consist of the following:

1) One off line card to paper tape and paper tape to card converter.

2) One paper tape reader and punch.

3) One computer.

4) Two Flexowriter typewriters.

5) Two magnetic tape read/write units.

6) One shielded storage cabinet for magnetic tape.

All equipment would be installed in the Data Processing Center. Input data would be converted from raw information to tape or cards by personnel from the department or division originating or requiring the data. In most cases, this would be data processing personnel under the organization proposed in Chapter IV. The computer would only be operated by data

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[54]Opinion expressed by Mr. J. L. Powell in a speech at the U. S. Naval Postgraduate School, Monterey, California, on March 8, 1962.

processing personnel. Under normal operating conditions, transactions for various departments would be accumulated until a sufficient number were on hand to make a computer run economical. If there was an urgent requirement for any particular records, they would be updated as often as necessary. It would not be necessary to accumulate like transactions in a group since the computer would be able to process mixed transactions. However, to save computer search time it is recommended that file slots be established for different transactions of each department and as transactions are received they be filed in the proper slots. This would batch like transactions. A schedule should be established for periodic printing out of all data in memory for each department, according to the degree of activity of the file and the needs of the department. In the case of the Supply Department, the fast moving material items should be placed on a different tape than the slow moving items. The fast moving item file would be printed out more frequently than the slow movers.

## V. ELIMINATING HUMAN ERROR

To quote the often heard cliche, "to err is human." The computer, however, displays uncanny accuracy. Unfortunately, the computer does not reason on its own and if man introduces absurd inputs into the computer, the latter will not question the information, but will process the data in

accordance with the stored program. These two facts dictate that every effort be made to eliminate human processing of the data, thus eliminating human error, and that the accuracy of all input data generated by humans be verified. This requires that the data processing system include two design features: reduction of human handling of data to the very minimum and verification of the accuracy of all input data.

Reducing human handling. To reduce human errors, the information or data to be processed should be transcribed from the basic document without human handling if possible. For example, when issuing material from a storeroom, it is recommended that prepunched cards be used into which must be entered only the quantity. Cash registers should be used that simultaneously punch a tape for input into the computer. Once data has been reduced to machineable input form, under no condition should it be converted by other than a machine process to other forms.

Verifying the accuracy of input data. Since the computer has no reasoning power, all input data must be carefully verified in two locations, namely, when it is originally transferred to machineable format and when it is entered into the computer. The first verification would be performed by carefully verifying the typed copy of the transaction which is produced by the Flexowriter at the same time the tape is punched.

For the second verification, the computer should be programmed to check input data whenever possible. For example, the program should require rejecting the input of an officer's file number if it were other than six digits. It should also be programmed to reject any transaction in which the stock number, unit of issue, nomenclature and price do not agree. Other sophisticated checks should be programmed into the computer to ensure the accuracy of all inputs. One system is the redundancy check digit, wherein as the digits are typed, the checker would multiply the digits by their proper weights and accumulate the sum. The computer would do the same thing and if the sums did not agree, the input data would be rejected for correction. A solution to these problems lies in an inexpensive optical reader which will transfer basic raw data accurately to a machineable format. There are several models on the market today, but their cost ($130,000) precludes their consideration for shipboard use. However, the industry is aware of this problem and a solution should be forthcoming in the near future.

## VI. INPUTS AND OUTPUTS

Careful consideration must be given to input and output devices to ensure maximum speed and also maximum possible accuracy. Many times the two are interrelated and one must be sacrificed for the other. Usually, this can be precluded by judicious use of off line equipment. Since input and output by punched card is generally much slower than paper tape

and magnetic tape, punched cards should not be used as an input or output device. However, to improve the accuracy of the input or output, it is recommended that off line conversion of cards to paper tape, and paper tape to cards be performed by machine. Usually raw data not already in card form would be converted to punched tape by Flexowriter typewriter. All transactions should be assigned a consecutive number and a transaction code to provide an "audit trail" and a plain language copy of all tapes punched should be retained on file for audit purposes. These same file copies could be used for manual operation in case of computer failure.

## VII. AUXILIARY STORAGE

Obviously all the programs required for all data processing on a ship and all data to be processed could not be stored in the core memory storage simultaneously. Accordingly, under the shipboard concept, both the programs and the data would have to be stored on magnetic tape reels or magnetic tape cards. Magnetic tape cards offer an advantage over magnetic tape reels in that random access would be available from the auxiliary storage, while only sequential storage is available on the tape. Hence, it would take longer to search a tape for data than to locate a card. When processing data for a particular department it would be necessary to first read the program into storage from the magnetic tape and then read

the data to be manipulated into storage. Upon completion of the processing the updated file must be removed from storage and placed back on the tape.

## VIII. BACKUP TAPES

To prevent possible damage to magnetic tapes by degaussing and deperming currents, ships should be provided with shielded stowage lockers. Ships should retain one spare program tape at all times, in the event the program on the tape in use is inadvertently erased. Ships should also retain a backup library file tape for each tape in use. For example, supply information should be accumulated until enough transactions are on hand to warrant a computer run. This would update the library tape with the latest information. At intervals of every two weeks, the contents of all tapes should be duplicated on two other tapes. One set of tapes would be packaged and mailed to the nearest Fleet Computer Programming Center with a plain language print out of the tapes. The purpose of the print outs is to permit the Fleet Computer Programming Center to reproduce the tape if it is damaged in shipment. The second tape should be stored on board in case the tape in use is inadvertently erased. By using this backup tape and the paper tape inputs subsequent to that date, it would be possible to update the file tape if necessary.

Keeping the aforementioned concepts in mind, the actual

EDP applications of each shipboard department will be discussed in the following paragraphs.

## IX. SUPPLY DEPARTMENT

It has been proved that Supply Department data processing can be adapted to EDP since similar supply procedures which are used ashore have already been successfully adapted to computer processing. Also, as was mentioned earlier, personnel at the Fleet Computer Programming Center, Pacific, have programmed and run shipboard commissary, general stores and repair parts programs on the AN/USQ 20 computer. The following paragraphs describe how the shipboard Supply Department administrative workload could be adapted to EDP utilizing current shipboard techniques. Obviously, when a computer is actually installed, changes should be made in the organization, procedures and regulations in order to best utilize the computer and to increase the overall effectiveness of the Supply Department. For simplicity the Supply Department operation has been broken down into the following discussion areas: Requisitioning and Accounting, Inventory Control, Commissary, Disbursing, Ship's Store and Clothing and Small Stores, Allowance List Maintenance and Equipage.

Requisitioning and Accounting. When funds are granted to the command, a transaction card (local form) and paper tape would be simultaneously typed and punched using a Flexowriter.

The documents would contain all the necessary data to completely describe the transaction including transaction code, transaction number, document number, authority, amount, type of transaction, accounting data (including amount budgeted to each department.) This information would then be entered into the computer memory (initially core storage and later transferred to magnetic tape.)

Requisitioning would be performed by simultaneously punching a paper tape and a transaction card. These documents would contain a transaction code, transaction number, date, requisition number, quantity, stock number, nomenclature, unit of issue, unit price, extension, departmental code and appropriate accounting information. On the basis of this input, the obligation of funds would be established and all information now contained in the requisition log and stock record cards would be entered on the tape. If a stock record card had not already been included in the auxiliary memory tape, this input would establish one. The output tape would then be run through the Flexowriter to create a plain language copy of the requisition. The five channel, coded paper tape would then be mailed or transmitted by radio teletype to the appropriate supply activity and the plain language copy of the requisition would be filed with the original request document. The paper tape requisition would contain all the information required by current requisitioning procedures.

Upon receipt of material, the EAM card accompanying the

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material would be used to punch a tape which would then be entered into the computer to record the receipt in the requisition log and in the stock record card section of the memory tape.

Upon receipt of the monthly summary, the information on the attached EAM cards would be transferred to paper tape and entered in the computer to clear the obligation and record the actual charge to the ship's allotment and the departmental budget. It would also close the entry in the requisition log. If the price or any other identification media differs from the information in the file, the console typewriter would so advise the operator.

Whenever information regarding the departmental budget, status of the allotment, requisition log or the status of an individual requisition was desired, the computer would print out the information upon request. However, in order to save time, this information should not be requested unless necessary, as bi-monthly print outs would produce this information automatically.

When stock number changes, price changes or similar information is received, it would be converted to paper tape if not already in that format and entered into the computer, instantly updating all stock records. However, the program should provide for the retention of the old information for reference. Then in the event that material was ordered or

received under the old descriptive data, the computer console typewriter would draw the operator's attention to the error.

If it is desired to replenish the stock to a three months endurance level, the computer could be programmed to issue the deficiency requisitions in tape format. If funds were not available to cover all requirements, the computer could be programmed to cut down stock levels to a lower endurance level. This could be accomplished in a matter of minutes.

The installation of the computer would make it possible for the Commanding Officer and Supply Officer to accurately control the ship's expenditures by getting statistical analyses of all types. For example, it could produce a listing of all paint issued to each department by cost, quantity, or type. It could produce a summary of all material of a particular type requisitioned by a department, all requisitions costing more than $5.00, or any other analysis desired.

After converting the requisitioning and accounting processes to the computer, the only tasks that would be required of office storekeepers would be transferring raw data to tape and filing the plain language copies of the tapes.

<u>Inventory Control</u>. Inventory control of all cognizances of material stocked by the Supply Department would be maintained on the magnetic tape auxiliary storage. The tapes would be divided into slow movers or fast movers, irrespective

of cognizances, to preclude excessive searching for items. The best time to establish inventory control tapes would be after completion of a supply overhaul. Each item stocked would have the following information recorded in the inventory control tape: stock number, brief nomenclature, component identification number, allowance quantity, unit of issue, unit price, quantity on hand, quantity on order, and history of transactions to date.

Issues from the storeroom would be reported on pre-punched cards giving all descriptive information necessary. Upon issue, it would only be necessary to punch in the quantity issued, the department or division and the consecutive transaction number using a portable punching device. Issue documents would be forwarded to the Data Processing Center daily where they would be batched and converted to paper tape by off line card to tape punch. The computer run would update the stock records and the ship's budget accounts.

If an issue causes the stock on hand to drop below a specified low level, the computer would so indicate on the console typewriter and would also produce a requisition on tape and establish the obligation. If stock levels remained satisfactory, the computer would just record the transaction. This is the "management by exception" principle of the computer which relieves the Supply Officer and Supply Department personnel of the necessity of manually reviewing stock levels frequently.

If it were desired to perform an inventory, the computer

could produce a tape which in turn would produce the inventory cards. The quantity inventoried would be punched in the cards. Upon completion, the cards would be transferred to tape and entered into the computer. Stock records would be updated and significant differences calculated and printed out by the console typewriter. The Supply Officer would thus be aware of the status of the department and the effectiveness of the inventory control procedures. If the Supply Officer only desired to inventory those items that had been issued during the last six months, the computer could produce these cards.

The computer could also be programmed to correct the low limits of the stock on the basis of issues. In this manner, the computer would not only insure that items in short supply were ordered promptly but would also adjust low limits in accordance with demands.

When material that was not stocked was required, a tape requisition would be prepared on the Flexowriter simultaneously with a transaction card. When this tape was entered into the computer it would establish stock records for this item and if repeated demand occurs, would calculate the stock level that should be maintained and would advise the Supply Officer of these facts on the console typewriter.

The only inventory control records maintained by the Supply Department personnel would be the duplicate transaction file and file of periodic print outs.

<u>Commissary Records</u>. Subsistence items would be

requisitioned in the same manner as general stores items except that they would be charged to the proper appropriation. Inventory would also be performed in the same manner as general stores and repair parts. Standard menu items and the quantity of each item required to prepare the menu for the various number of persons that the ship could be expected to serve would be programmed into the computer giving stock number, nomenclature, unit of issue and price. When the menu had been approved for the week, each item on the menu would be punched in a paper tape and entered into the computer. It would then compute the quantity of each item that should be drawn each day to support the menu. This tape could then be used to punch a stub requisition which would be used to draw the subsistence items each day. The computer would also tell the Supply Officer, in advance, the cost of the daily ration for each day of the week and the accumulated average cost to date. After issue, the stub requisition would be returned to the Data Processing Center for processing as an actual expenditure. If the quantity initially calculated by the computer had to be altered, a new stub requisition would be punched and the running average corrected accordingly. Other transactions such as surveys, issues, sales to other messes, cash sales, and similar would initially be handled by a stub requisition or receipt expenditure invoice and would subsequently be converted to punched tape for input into the computer. All transactions affecting balance sheet captions would be accumulated,

[illegible]

so that at the end of the accounting period the computer would instantly compute the commissary returns. The computer could also print out inventory sheets for the periodic inventory and perform all the necessary computations.

The computer would maintain stock levels in the proper range and would be capable of giving the Supply Officer statistical analyses of actual consumption of individual subsistence items so that the endurance of the ship could be maximized with the proper ratio of the subsistence items that the particular ship uses.

Disbursing. Payroll computation was one of the first applications of EDP in industry and the military services were also quick to apply payroll to EDP. The Navy Finance Center, Cleveland, Ohio is using computers to calculate pay and there is no reason why any other command could not perform this operation. Basically, each entry on the pay record for each person would be placed in magnetic tape memory. All routine transactions affecting pay would be converted to tape and entered into the computer. At each pay day, or at other times when required, the computer would compute the pay of any or all persons on the ship, punch the amount due on paper tape and this paper tape could be run through the Flexowriter to automatically print the payroll. Special precautions must be taken, however, to ensure that "audit trails" provided meet the requirements of the Comptroller of the Navy.

Ship's Store and Clothing and Small Stores. Requisitioning, accounting and inventory control of material carried in Ship's Store and Clothing and Small Stores could be performed in a manner similar to the procedures already discussed for these functions. Purchase orders and dealers' bills could be handled in a manner similar to requisitions with modifications to record the actual payment of the dealer. Transfers from the bulk storeroom to the issue storeroom would be made on a prepunched card so that only the quantity would be punched into the card at the time of transfer. This card could then be converted into a punched tape to provide an input into the computer so that it would maintain running inventories of material in the bulk storeroom or of material issued to various activities. Whenever possible, cash registers which also record sales on punched tape should be used in the retail activities. By appropriately coding classes of items such as tobaccos, sundries, leather goods and uniform accessories, the computer would not only be able to maintain the current status of ships service activity sales, but would also reveal which classes of items were or were not selling. All transactions that affect balance sheet captions would be accumulated, so that at any time the status of the Ship's Store and Clothing and Small Stores account could be printed out. The computer would also be able to print out inventory sheets and cards for the periodic inventory and perform all the necessary

computations. It could also be programmed to compute selling prices for new items or adjust prices on old items as desired by the Supply Officer.

Allowance List Maintenance. The ship's complete allowance list would be stored in the auxiliary memory. Accordingly, changes in identification media and allowances of items could be rapidly made and the ship's allowance would always be current. Likewise, tables of substitute stock numbers and superceded stock numbers would be retained in auxiliary storage so that rapid conversions could be made if desired. These tables would be especially useful if a ship had an emergency requirement for an item and desired to determine if a substitute, superceded or replacement item was available.

Equipage. A record of all equipage items would be placed in auxiliary memory. This would permit the records to be updated for stock number changes, inventory, survey and procurement action. It would also permit the immediate calculation of shortages and would permit scheduling inventories.

Supply Department summary. The introduction of a computer and shipboard EDP would permit the Supply Department to process all routine data by computer. This would have the following effect on Supply Department personnel.

1) Office records. All office records would be adapted to electronic data processing and the only duties

remaining would be the filing of transaction records and requisitions and converting raw data to punched tape. This would eliminate stock control personnel, requisition desk personnel and allotment and budget maintenance personnel. Correspondence would still require manual handling.

2) Storeroom personnel. The duties of storeroom personnel would be reduced to maintenance of storerooms and receipt and issue of material. It is recommended that all fast moving items (items with allowance of three or more or history of three or more issues within a two year period) be stored in one storeroom.[55] This would minimize maintenance and expedite issue of material. This would also permit a reduction of some storeroom personnel.

3) Disbursing personnel. The duties of disbursing personnel would be reduced to transferring raw data to punched tape, handling particularly unusual transactions, and physically assisting with payment of the crew. Accordingly, it is estimated that one disbursing clerk could be eliminated for every five hundred pay records maintained, except that a minimum of one must be retained on board.

4) Commissary, Ship's Store and Clothing and Small Stores. Since only the records of these divisions will be affected by shipboard EDP, only personnel engaged in the actual

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[55]Many type commanders and supply overhaul activities classify items with an allowance of three or more or with a history of three or more issues in a two year period as fast movers.

processing of records could be eliminated.

5) Equipage and Allowance List. Since all equipage records and allowance lists would be mechanized, all personnel performing these functions could be eliminated.

Listed below is a summary of enlisted personnel that could be eliminated when EDP is fully implemented in the Supply Department afloat. These numbers are minimums and are actually understated since they do not take into consideration reductions in services, habitability, living space, working space, and stores required to support personnel eliminated.

| | Destroyer Type | Aux. Type | Carrier Type |
|---|---|---|---|
| Inventory Control | 1 | 2 | 4 |
| Requisition Desk | 1 | 1 | 2 |
| Allotment Control | 0 | 1 | 1 |
| Storerooms | 0 | 2 | 6 |
| Disbursing | 0 | 1 | 3 |
| Commissary | 1 | 1 | 1 |
| Ship's Store and C & SS | 1 | 1 | 1 |
| | 4 | 9 | 18 |

## X. PERSONNEL

All personnel records would be handled by electronic data processing. In fact, all personnel information and data coming to the ship from shore activities or going from the ship to shore activities would be in machineable format. This would preclude the necessity of conversion of data to machine input format both afloat and ashore. The personnel records and leave record of each person would be maintained

on the magnetic tape auxiliary storage. All changes in status, promotion, detachment and similar actions would be converted to punched tape for entry into the computer. The same input information would also be used for other purposes such as disbursing, training records, Watch Quarter and Station Bill assignment, medical and dental records. Division officers would be furnished print outs of personnel in their division. This system would also provide the command with a means of rapidly determining information or statistics within the command. For example, rather than have personnel manually search the records of the entire crew, the computer could print out in seconds lists of all men with specified periods of service, men whose enlistment expires within a certain period, men who have been aboard a certain period, men who have foreign language ability, men who have certain technical qualifications, etc. The computer could also maintain leave schedules and other administrative records. Routine and when occurring reports pertaining to personnel would be produced on punched tape and mailed in this form to the appropriate activity. Consequently even though the bulk of the personnel and personnel functions could be eliminated, the command would have better personnel records and information than is now available.

## XI. SHIP'S OFFICE

The shipboard computer would prove very useful as a data retrieval device. When official mail was received for

the ship, complete identification information and three or four key words which describe the subject, the file location and the shipboard routing would be punched on paper tape. This information would then be placed in file memory. The computer would be programmed to tell if correspondence with the particular key words had been misrouted. It would also be able to give a listing of all correspondence received under any particular key word. Accordingly, if all references on a particular subject were needed, the computer would be interrogated using the key words. A list of all references pertaining to the key word would be produced. The computer could also be programmed to print shore patrol lists, liberty lists, and mailing lists. It could prove very useful in producing the plan of the day, for if various events were scheduled and entered in the computer by date, it would print out all events scheduled for a particular date without further notification.

## XII. MEDICAL AND DENTAL DEPARTMENTS

The requisitioning, accounting, inventory control and inventory of medical and dental supplies and material would be performed in exactly the same manner as other shipboard material. Likewise, medical and dental records would be handled in the same manner as personnel records. The computer could also be programmed to schedule dental appointments,

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[illegible]

[illegible]

annual x-rays, innoculation schedules and similar routine medical and dental functions. When the Medical Officer placed a man on the sick list, a paper tape would be punched giving all the appropriate information. This input would then be used to print a daily sick list, and make a simultaneous entry in the man's health record. The computer would also be invaluable in accumulating statistics on the medical experience of the crew.

The computer could also be used to diagnose maladies on the basis of the symptoms observed. These symptoms would be entered into the computer. The computer would match these symptoms with a stored program which related different diseases to symptoms.[56] The output would be a list of diseases that would be indicated by the symptoms noted and instructions on what further tests to make. This system would be particularly useful on smaller ships which do not have Medical Officers attached.

## XIII. ENGINEERING DEPARTMENT

The use of shipboard electronic data processing would permit the Engineering Department to accumulate necessary information that was never before possible. The machinery

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[56] Robert S. Ladley, Lee Blusted, "Computers in Medical Data Processing," Operations Research, Vol. 8 No. 3, (June 1960), pp. 299-310.

history of each piece of machinery installed on the ship would be placed in magnetic tape storage. All information pertaining to a particular piece of machinery including hours in use, hours unavailable, cost of maintenance, man hours of maintenance required and similar information would be recorded. This would permit the Engineering Officer to accurately evaluate the engineering plant. Preventive maintenance requirements for each piece of equipment would be placed in memory and the computer would schedule the maintenance and report progress and any backlogs. Likewise, job orders for other departments would be placed in memory and scheduled in accordance with a priority assigned each job. Costs and man hours as well as productive time of individual repair personnel would also be accumulated. Daily operating information and consumption figures would be entered into the computer, total accumulated and the monthly summary automatically computed. Shipyard and tender repair jobs would be written up as the necessity became apparent and printed out by computer when the ship was notified to submit work lists. Boat and vehicle history and cost records would be maintained by computer as would blue print indexes. Obviously, the computer could save the Engineering Department many office personnel and allow technical personnel more productive time.

## XIV. GUNNERY OR DECK DEPARTMENT

The history record of each piece of gunnery equipment and each compartment on the ship would be maintained in magnetic tape storage. Preventive maintenance required for each item would also be placed in memory and the computer would schedule preventive maintenance. Any repairs, inspections or maintenance performed on any compartment or equipment would be converted to a punched tape and entered into the computer auxiliary memory. This input information would contain such information as date, work performed, persons performing work, cost of material and similar information. A record of cleaning gear issued to divisions and departments could also be entered in memory. Ammunition inventory records would be maintained in the same manner as Supply Department material. With this information in the computer, the Gunnery Officer and/or First Lieutenant could be quickly furnished with statistical data necessary to manage and control the respective department effectively. In addition the tedious job of maintaining ordnance history records, and current ship's maintenance project records would be reduced to simply punching a paper tape with the necessary information.

## XV. COMMUNICATIONS

The computer would be used to maintain inventories of

registered publications including custodians, changes made and changes pending. It would schedule the preventive maintenance of communication and electronic equipment, maintain the history of each equipment including the hours in use and the cost of repairs. It would also be used to maintain the ship's current listing of telephone numbers and would be used to maintain a file of all messages received by the ship.

## XVI. NAVIGATION

The computer would be programmed to instantly solve the Navigator's celestial observations, and it would also be used to maintain the inventory of charts and the corrections that apply to each chart.

## XVII. REPAIR AND AVIATION DEPARTMENT

The computer would perform data processing for the repair and aviation departments in a manner similar to the same tasks performed for other ship's departments.

## XVIII. TRAINING

The ship's training program and personnel training records would be placed in auxiliary memory in the computer. The computer could then produce daily training schedules, report programs that are behind schedule, and permit rapid correction and updating of the various programs. Personnel

training records could very easily be maintained current by simple punching a tape input for personnel completing courses, classes or practical factors. The computer could also be used to actually run war games, battle problems and damage control drills.

## XIX. OFFICERS AND CPO MESS RECORDS

The most troublesome records to maintain properly aboard ship are the records of the private messes. This is primarily due to the unfamiliarity of the respective treasurers with mess records and accounting. The private mess records would be consolidated and adapted to electronic data processing. This would eliminate the work involved in maintaining these mess records and insure that they were always correct.

## XX. LANGUAGE TRANSLATION

When visiting in foreign countries there would be many occasions when it would be desirable to translate official ship's history and programs into a foreign language. If the ship were provided a magnetic tape to translate English to foreign languages this could be very easily accomplished. The material to be translated would be punched into paper tape. The computer output would be the translation which would be run through a Flexowriter to obtain the print out.

## XXI. STAFF LOGISTICS

The computer could be very successfully employed by an embarked staff in operations research and feasibility studies. It could prove invaluable in planning and executing air sorties, ship to shore movements, search patterns and similar exercises including probability and simulation with large amounts of data and many variables. For example, a complete ship to shore model could be built, programmed and placed on magnetic tape. The command planning a landing would then enter into the computer various variables including number of personnel, tanks and artillery involved and the computer would automatically compute the logistic requirements for the operation. Models could also be provided for similar military operations and for war games for use in training staff personnel.

## XXII. GENERAL QUARTERS USE

The computer would prove invaluable during General Quarters by making damage control information instantly available to repair personnel. The information would include all circuits, steam, water and oil cutouts that must be secured in the event of fire or flooding for each compartment of the ship. It would also provide a listing of compartments which should be counterflooded in event any compartment or compartments were flooded, information on the

quickest means of dewatering a compartment and the locations of the nearest portable pumps, tools, shoring, sprinkling systems, and magazines.

## XXIII. SUMMARY

It must be concluded that at least seventy-five per cent of the data processing workload afloat could be performed by a computer. It must also be concluded that the computer could do the processing more accurately and more quickly and could perform tasks that are not possible under the present manual methods. It would permit large reductions of personnel in the supply and personnel areas and lesser reductions in the other departmental areas.

# CHAPTER IV

# CAN THE COMPUTER AND PERIPHERAL EQUIPMENT BE ACCOMMODATED ABOARD SHIP?

Chapter III indicates the almost inexhaustible number of applications of the computer to shipboard data processing. Hence it is established that electronic data processing can be effectively used afloat. The next question, and the most important question, is whether the computer and its peripheral equipment can be accommodated aboard ship. This is a difficult question to answer and in determining the answer there are many aspects which must be considered. In the following paragraphs each of the following considerations are discussed: physical size, air conditioning requirements, cost, maintenance, programming procedures, psychological aspects, training requirements and organizational changes.

## I. PHYSICAL CONSIDERATIONS

The trend in computers and peripheral equipment is toward smaller, lighter, more reliable components with lower power requirements and ability to operate at normal temperature ranges. Thus there is no question but what the computer of the future will find its place aboard ship. The question is can they be placed aboard ship today. Some of the characteristics that must be considered before concluding

that a computer can be installed on a naval vessel are discussed below.

Size and Weight. The size and weight of the type of computer suitable for shipboard installation is no problem. The large scale, general purpose computer AN/USQ 20 that is being installed on all major Navy ships, weighs 2300 pounds and is only 33" deep x 37" wide x 72" high.[57] This is the approximate size of the usual household 8 cubic foot refrigerator. Its primary power is provided by a 60 cycle input, 400 cycle output motor alternator. The diode and transistor circuitry only require 2500 watts. Another suitable shipboard computer, the AN/UYK1 is only 16" deep, 20" wide and 59" high with a total weight of 550 pounds.[58] This computer is less than half the size of the AN/USQ 20.

Peripheral equipment that would have to be accommodated would consist of the following:

| | DECK AREA | WEIGHT |
|---|---|---|
| Two magnetic tape handlers, each 30x24x60, weight 1400 pounds | 10 sq. ft. | 2800 pounds |
| One paper tape punch and reader, 43x24x48, weight 250 pounds | 7.2 sq. ft. | 250 pounds |

[57]Paul Conlin, "Combat Computer," Armed Forces Management, Vol. 7 No. 10, (July 1961), p. 15.

[58]Thompson Ramo Wooldridge, Inc., AN/UYK 1 Computer Description., p. 23.

| | DECK AREA | WEIGHT |
|---|---|---|
| One shielded tape cabinet | 10 sq. ft. | 200 pounds |
| Two Flexowriters (slightly larger than an electric typewriter) | 24 sq. ft. | 600 pounds |
| One off line tape to card and card to tape converter | 7 sq. ft. | 300 pounds |

To give the reader an idea of sizes of equipments involved, the computer is comparable to a normal household refrigerator, each magnetic tape unit, the size of a public telephone booth, and the paper tape punch and reader is the size of a four drawer legal file cabinet, as is the tape to card and card to tape converter. So the computer center would contain equipment comparable to three file cabinets, one refrigerator and two telephone booths, plus two desks with electric typewriters. Obviously, these will fit in almost any compartment aboard ship.

In connection with size trends of computers, it is interesting to note that the AN/USQ 20 which takes up nine square feet of floor space has the equivalent workload capability of two UNIVAC 1103 computers, each of which takes up 1400 square feet of floor space.[59] It is also interesting to note what the manufacturers predict in the size of future computers. IBM in its General Information Manual

[59]Conlin, loc. cit.

advises that

> Computers, by 1980, will probably be quite different from today's. Storage and processing units as powerful as today's largest may be the size of a television set, perhaps smaller.[60]

It is also appropriate to note that at the Western Joint Computer Conference in May 1960, Mr. John M. Salzer, Director Intellectronics Laboratories, Ramo Wooldridge, Canoga Park, California stated that

> From our brief review of things to come, we can conclude without a doubt that the advances in our technology will be startling and indeed they seem unlimited. Computers will be small enough to become vastly more useful in many new applications, and powerful enough to perform almost any task.[61]

We can thus conclude that size is no problem now and will be no problem in the future.

Shock Resistance. The use of solid state circuitry makes it practicable to design a computer that is completely shock resistant and unaffected by the motions of the ship. However, all commercial computers are not shock resistant and this requirement would have to be specified in any procurement action.

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[60] International Business Machines Corporation, General Information Manual, (White Plains, New York, 1960), p. 11.

[61] John M. Salzer, "Data Processing-What Next?", Proceedings of Western Joint Computer Conference, Vol. 17 (May 3-5 1960), p. 197.

## II. AIR CONDITIONING

The advent of solid state computers using diode and transistor circuitry has reduced the power required by the computer to the point where air conditioning is not required. The most critical component to temperature change is the magnetic core storage, but recent technical papers report that cores have now been successfully operated over temperature ranges of -55°C to 125°C.[62] Some manufacturers have built air conditioners into their computers and these require no additional air conditioning, but they do require a water source. Another technique that manufacturers are using is to design computers to operate at elevated temperatures. Then the requirement is to maintain the heat in the computer center rather than air condition the space. This technique was employed in the Navy's newest largest computer, the LARC, which is installed at the David Taylor Model Basin, Washington, D. C.[63] The AN/UYK 1 computer, which is suitable for shipboard use, is designed to operate at temperatures

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[62] R. S. Weisz and M. Rosenberg, "Wide Temperature Range Coincident Current Core Memories," Proceedings of the Western Joint Computer Conference, Vol 19 (May 9-11, 1961), p. 207.

[63] Arthur F. Draper, "Computers," Sperryscope, Vol. 15 No. 10, (Third Quarter 1961), p. 19.

between 32 degrees F and 122 degrees F.[64] So no air conditioning would be required for this computer.

However, there are factors other than the computer to consider when determining whether a computer center should be air conditioned. Probably the most critical device in a data processing system is the magnetic tape reader. A little piece of dust in the reader may alter the reading and introduce an error in the computer. Computers are designed to pick up this error, however it still occurs and slows the processing. Other difficulties occur in the handling of punched cards and punched tape under humid conditions, or after the tape and cards have been stored in high humidity spaces.[65] Also many of the most efficient tape units require air conditioning.

Consequently, although computers of the future will not require air conditioning, it is recommended that the computer center be air conditioned in order to obtain optimum operating conditions.

## III. COSTS

Costs are deceptive to say the least. It has been a common error in the past to underestimate costs and overestimate

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[64]Thompson Ramo Wooldridge, Inc., <u>AN/UYK 1 Computer Description</u>. p 23.

[65]Rollin S. Thompson, Special Representative, Burroughs Corporation, personal letter of March 29, 1962.

savings when determining whether to install a computer or not.[66] This is partially caused by the fact that people fail to include the costs of peripheral equipment which is usually equal to the cost of the computer, that more uses are found for the computer than originally planned and the fact that resistance to change or suspicion and distrust prevent the total surrender of all data processing to the computer. Accordingly, when calculating costs and savings, the writer will be very, very conservative, will include all possible costs, using the cost that would apply to a government activity buying one of a kind in equipment. Actually, many manufacturers that the writer contacted indicated reductions up to thirty percent if lots of 20 computers were purchased. Therefore, the net costs discussed are actually maximum costs rather than minimums.

The appendix gives the breakdown of some typical computer systems available today that in the writer's opinion would perform the job desired. These are not ultra sophisticated systems but unquestionably would produce the desired results. (Note, however, that none of these systems are recommended for installation for reasons that will be discussed in Chapter V.) The absolute maximum cost per installation would be $300,000.00 and the minimum costs without quantity

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[66]"But Original Targets Missed," Navy Management Review, Vol. 5 No. 10, October 1960, p. 8.

discounts would amount to $105,000.00 per installation.

Captain J. Garrett, USN has made an extensive study in the area of the shipboard manning problem and new technology. Quoted below is Captain Garrett's computation of savings created by the reduction of on-board count of officers and enlisted men.

> Some of the savings that could be achieved by the reduction of the on-board count of officers and enlisted men by one, for the 20-year life of a ship, are indicated by the table that follows. These estimates are based on 1960 wage and equipment costs and not the escalating costs that might be anticipated.
>
> Shipboard Manning Costs (20-Year Ship Life)

| | Per Officer | Per Man |
|---|---|---|
| Pay and allowances | $130,000 | $ 90,000 |
| Training and travel amortization | 60,000 | 20,000 |
| Retirement annuity | 13,000 | 9,000 |
| Habitability space | 6,750 | 2,700 |
| Habitability equipment | 2,250 | 800 |
| | $212,000 | $122,500 |

> Additional savings resulting from reductions in requirements for house-cleaning, stores handling, personnel administration, personal safety equipment and personnel access provisions have not been included in these estimates.[67]

Assuming that the average Navy ship is ten years old, the costs derived by Captain Garrett for a twenty year period will be reduced by one half. Then the savings that would be experienced by the reduction of one officer or one

[67] Captain J. Garrett, "New Technology and the Shipboard Manning Problem," Naval Research Reviews, October 1960, pp. 2, 3.

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enlisted man from the on-board count would amount to $106,000 or $61,000 respectively. However, industry has found that for every three persons displaced by electronic data processing, one person must be added to operate and maintain the equipment. While it is expected that in the case of the Navy, the bulk of the personnel required to operate and maintain the computer would be obtained by training personnel on board, for the purposes of conservatism, it will be assumed that the one for three average experienced in industry would also prevail in the Navy. Thus the savings experienced for a decrease of one officer or one enlisted person would be further reduced by one third to $71,000.00 and $41,000.00 respectively in order to compensate for computer operating and maintenance personnel added to the on-board complement or to support activities.

Table I shows the combinations of the number of officers and/or enlisted personnel that would have to be reduced from the on-board count to realize savings in the $105,000 to $300,000 dollar range. Assuming that a system costing $300,000 is selected, the system will <u>more</u> than pay for itself if it will replace 2 officers and 4 enlisted men, or 1 officer and 6 enlisted, or 8 enlisted. It is to be emphasized, however, that these figures are based on the very minimum savings to be expected compared with the maximum current costs of equipment. Since computers are becoming more sophisticated

each day, each new model will be capable of performing more tasks thus creating greater savings in the future. Likewise the cost trend in computers and equipment is very decidedly downward. In fact, Arthur F. Draper, Remington Rand Univac Division Marketing Executive in a recent article stated that "the possibilities of future reduction of computer size and cost tend to stagger the imagination."[68]

Since the wages of man keep rising and computer costs are decreasing, it can be expected that even less personnel would have to be reduced from the on-board count in the future in order to realize net savings.

A review of the tasks enumerated in Chapter III that can be performed by the computer reveals that in any ship with the personnel allowance of a destroyer or greater there would be no problem effecting a reduction of personnel sufficient to compensate for the installation costs of the computer. On ships with personnel allowances larger than a destroyer great savings could be realized, and on ships having fewer personnel than destroyers, such as an LST, only minor reductions in personnel could be effected. However, the greater savings on the larger ships would more than pay for net costs experienced on smaller ships. Under any condition, any plans

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[68]Arthur F. Draper, "Computers-Some History and Background," Sperryscope, Vol. 15 No. 10, (Third Quarter 1961), p. 18.

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TABLE I

SAVINGS IN THOUSANDS OF DOLLARS FOR COMBINATIONS OF OFFICERS AND/OR ENLISTED MEN REPLACED BY ELECTRONIC DATA PROCESSING

| No. of Officers | No. of Enlisted | Savings in Thousands of Dollars |
|---|---|---|
| 5 | 0 | 355 |
| 4 | 1 | 325 |
| 4 | 0 | 284 |
| 3 | 2 | 295 |
| 3 | 1 | 254 |
| 3 | 0 | 213 |
| 2 | 4 | 306 |
| 2 | 3 | 265 |
| 2 | 2 | 224 |
| 2 | 1 | 283 |
| 2 | 0 | 142 |
| 1 | 6 | 317 |
| 1 | 5 | 276 |
| 1 | 4 | 235 |
| 1 | 3 | 194 |
| 1 | 2 | 153 |
| 1 | 1 | 102 |
| 1 | 0 | 71 |
| 0 | 9 | 369 |
| 0 | 8 | 328 |
| 0 | 7 | 287 |
| 0 | 6 | 246 |
| 0 | 5 | 205 |
| 0 | 4 | 164 |
| 0 | 3 | 123 |
| 0 | 2 | 82 |
| 0 | 1 | 41 |

for installation of data processing on ships should not neglect the smaller ship because a net savings would not be attained on this type vessel. If any ship requires an electronic data processing system, it is the smaller ship with the same scope of paper work as the larger ships but with fewer personnel to process it.

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The very conservative cost and savings figures just discussed conclusively prove that net savings can be obtained on the majority of the ship types and on the fleet as an entire unit if data processing is installed and it is properly utilized. However, comparisons of costs and savings should not be the sole criterion in considering whether to install electronic data processing or not. The criterion that must also be used, is whether the advantages and improvements resulting from installation of the computer system or its contribution to military operational capabilities outweigh the costs. In this area it must be considered whether the computer can accomplish all the present procedures more efficiently than men, and whether the system will also perform more worthwhile tasks than were possible before installation. Mr. E. Wainright Martin, Jr. neatly sums up this criterion when he says

> We should not attempt to maximize the value of data processing results nor to minimize the cost of data processing, rather we should maximize the data processing profit which is the difference between the value of the results of data processing and the costs of obtaining these results.[69]

Accordingly, it is necessary to compare the total profit to the Navy obtained by installing EDP afloat against the actual costs, which have already been proved to be net

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[69]E. Wainright Martin, Jr., Electronic Data Processing An Introduction (Homewood: Richard D. Irwin, Inc., 1961), p. 329.

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profits rather than costs in most instances. The actual profits to be realized are almost innumerable but some of the more important ones are discussed below.

Improved logistic and operational readiness. The most compelling reason for installation of electronic data processing afloat is in reality to optimize the logistic and operational readiness of the ship. Almost every application of the computer contributes to this goal. The installation of a computer coupled with the trend toward less costly miniature electronic repair parts will instigate a chain reaction that will finally attain the absolute maximum readiness permissable within the defined parameters. For example, sophisticated inventory control procedures employed by the computer will minimize risk while also minimizing cost and storage space. This will in turn permit increasing the range of repair parts carried which will further increase the readiness of the command. Thus the final result of installing electronic data processing afloat will be optimal logistic and operational readiness.

Improvement of inventory control. The Supply Overhaul Program has proved beyond a doubt that ship's personnel are unable to keep up with the current shipboard data processing workload. This has been obvious to all concerned, and as a

result all ships now receive a supply overhaul whenever they undergo a regular shipyard overhaul. The cost of actually performing this overhaul and the same results obtained by the supply overhaul could be realized by installing EDP aboard ship. The inability of ships to perform all the required functions was emphasized by the Supply Officer of the USS Klondike AR 22

> Ships are not adequately manned in storekeeper ratings to adequately carry out all the paperwork that the book calls for. There is a shortage in both quantity and quality and frequent rotation of personnel proves a large problem.[70]

Obviously, inadequate inventory control procedures can also adversely affect the ship's material and logistic readiness, which is the prime function of the Supply Department afloat.

Improved accuracy of data processing. The computer has proved beyond a doubt that it has uncanny accuracy and in this aspect, is far superior to the human being. With the advent of electronic data processing ashore whereby inaccurate and absurd requirements go unnoticed, inaccuracy afloat can be very costly in many respects. For example, the wrong material may be received, it may delay processing time in that the computers ashore may reject the incorrect requirement and

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[70]CDR E. J. Rinetti, SC USN in personal letter of 10 February 1962.

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the delay in obtaining the required item may seriously affect the command's ability to carry out its assigned mission.

Reduced shipboard workload. The installation of the computer will reduce the shipboard workload for all departments by performing routine clerical work and eliminating duplication of effort. This will in turn allow the onboard count to be reduced and free other personnel to deal with the more important aspects of management and command.

Improved timeliness of data processing. The use of electronic data processing afloat will permit required reports to be submitted almost instantaneously thus improving the value of the reports both to the ship and other interested activities.

Reduction of file storage space and office equipment. The utilization of the computer and the maintenance of all routine records on magnetic tape will drastically reduce the file storage space. Likewise, the computer will permit large reductions in the amount of office equipment required including desks, typewriters and file cabinets.

Capability of rapid increase in work load. The installation of the computer afloat will permit almost instantaneous and unlimited increases in data processing workload afloat without an increase in personnel. This ability to

rapidly expand would improve the mobilization capability of the fleet immeasurably. Likewise, this capability will permit greater material and logistic readiness by permitting large increases in number of items stocked and wider dispersion of stock. Conversely, the computer will permit the ship to operate effectively in the face of severe personnel casualties or shortages.

Capability to perform new tasks. The installation of the computer will provide the command with the ability to perform necessary tasks that are presently beyond the capability of ships' personnel. It will permit the command to analyze its operation and to obtain statistics that will permit greater efficiencies within the command, that will permit the practice of operations research or management science, that will permit the Commanding Officer to better allocate funds and other scarce resources and provide more accurate and timely information on which to base decisions.

Decrease in pipeline personnel and material. The use of the computer afloat for handling personnel and material reports and requirements and the transmission of data in machineable format will permit a large decrease in the number of personnel or amount of material in the pipeline going to and from the ships.

Decrease in workload and processing cycle ashore. The utilization of the computer afloat will enable the ship to transmit data to shore activities or receive data from shore activities in machineable format. This will preclude the necessity of the shore activity employing large numbers of keypunch operators and clerks to convert machine coded documents to readable format and vice versa. The errors attendant to this practice will also be eliminated. Likewise, it will decrease the processing cycle ashore making the shore establishment more responsive to fleet requirements.

Another important factor is that the use of the computer for data processing afloat will ensure better inventory control and will greatly reduce the total number of demands placed on shore activities and also the number of emergency demands. This in itself, with the accompanying decrease in premium transportation requirements, will produce an appreciable savings at shore activities.

Thus while the net costs of installing a computer aboard ship are minimal, in fact, even profitable, on large ships, the overall improvements and savings that would be realized by the Navy are tremendous.

## IV. MAINTENANCE

It is impossible to consider maintenance without also considering reliability. Likewise, it is necessary to discuss

the maintenance considerations in connection with the computer itself, separately from the peripheral equipment, since the latter has moving parts while the computer has very few. Accordingly, the computer and the peripheral equipment will be discussed separately.

Computer manufacturers have stressed reliability in their product from the beginning because they realized it would have to be used constantly to be economical and because the company usually rents the equipment and has to maintain it with their own employees. As a result they have achieved marked success. Not only have they produced high reliability, but they have proved consistently accurate in their ability to predict reliability. Proof of this reliability is presented in the following examples.

Daystrom Systems Division furnished a computer to Louisiana Power and Light Company to completely automate a new station. Daystrom predicted the computer would operate for six months with 99% availability. (Note they said availability, not reliability, which means that time for preventive maintenance is non-available or down time.) The computer has run eight months, day and night, at 99.994% availability, having been shut down only twenty minutes in the eight month period.[71]

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[71]"Computers Start to Run the Plants," Business Week, No. 1627, (November 5, 1960), p. 50.

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Similar reports have been received from afloat installations of computers. Dr. Joseph H. Engel, of the Operations Evaluation Group, Washington, D. C., stated in a talk at the U. S. Naval Postgraduate School that he was aboard the USS Oriskany when one of the AN/USQ 20 computers experienced its first down time since installation. This was after 2000 hours of operation.

In another example, Thompson Ramo Wooldridge predicts that the estimated mean time between failures of their AN/UYK-1 computer is 896 hours.[72]

This extraordinary high degree of reliability must be attributed to the initiative and engineering expertise of the technical staffs of the manufacturers. However, they have not ceased in their efforts to improve their products and as computers are used for more and more control or real time operations, reliability is receiving even more emphasis.

There are two principal methods of improving reliability, improving the individual components and improving the circuitry. The probability that any complete electronic system will function as intended is found by multiplying together the probabilities of the individual components and

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[72]Thompson Ramo Wooldridge, Inc, <u>AN/UYK-1 Computer Description</u>., p. 23.

the connections making up the system. With the present state of development of reliable electronic devices, the soldered connections which outnumber the components many times over represent more of a collective reliability hazard than do the components themselves. If a system consists of five components and connections and the components have a probability of survival of 90%, together the probability of survival is .9 x .9 x .9 x .9 x .9 which equals .59. This shows that a reduction in the number of components and connections will increase the reliability of the system much more than an improvement in the reliability of the component itself. Consequently, two attacks are being made to improve reliability: Increase the reliability of the components and decrease the number of components and attendant connections. The latter method is receiving the most concentrated effort.

Solid state circuitry. The use of semi-conductor solid state transistors and diodes has completely eliminated all electron tubes from computers. The AN/USQ 20 computer contains 3776 identically packaged printed circuit cards on which are attached the diodes and transistors which are completely encapsulated. The computer consists of thirteen roll out drawers (called cookie sheets in computer lingo) that can be pulled out to expose the circuit cards. Each card contains a set of prongs which are inserted into female receptacles in

the drawer. Therefore, to replace a defective circuit card it is only necessary to open the drawer, remove the inoperative circuit card, insert a new one and close the drawer. The transistors and diodes consume less power than vacuum tubes, so less heat is generated. They also have a longer life than electron tubes and in fact can't wear out or burn out when properly applied. If there is a failure, a built in test device will quickly reveal the faulty circuit and it can be quickly replaced in the manner described above.

Magnetic core memory. The use of the magnetic core memory improves the reliability of the computer since it contains no moving parts. It also has increased the speed of computation, decreased power requirements, and decreased the size of the computer. However, the use of cryogenic properties which will be discussed later, indicate that even greater improvement may be expected of core memories.

Automation. Wherever possible, manufacturers are replacing human hands with machines in the manufacturing process in order to decrease the number of human errors and increase the reliability. During a visit to the International Business Machines Corporation plant at San Jose, California, the writer observed a computer controlled machine completely wiring the back panel of a computer with thousands of hair-like wires. IBM representatives reported that not only were

all errors eliminated, but the connections were better than those made by humans. Manufacturers have also improved reliability by employing welded or wrapped wire circuit connections rather than the normal soldered connections.

Microsystem electronics. The history of microsystem electronics may be traced through the following successive stages: miniaturization, subminiaturization, microminiaturization, thin-film integrated circuits, semi-conductor integrated circuits and finally functional blocks.[73] Microsystem electronics is leading up to smaller and smaller electrical elements which can be integrated into a single chunk of material.[74] Thus manufacturers have effectively reduced the number of parts by combining them into a single unit. Finally it is predicted that circuits will end up with a solid state material which performs in an identical manner with the circuit desired. Reliability will be increased because there will be fewer units and fewer connections between units that may fail.

Two dimensional microminiaturization. Two dimensional microminiaturization seeks to eliminate thickness in the circuit by forming the elements of a circuit directly upon a

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[73]Peter B. Myers, "A Survey of Microsystem Electronics," Proceedings of Western Joint Computer Conference, Vol. 19, (May 9-11, 1961). p. 63.

[74]J. S. Kilby, "Interconnection Techniques for Semi Conductor Networks," Ibid., p. 87.

[illegible] wafer. Thus capacitors, resistors and other components are processed, along with their interconnections, upon an insulating ceramic wafer usually by thin-film depositing techniques such as evaporation or sputtering. This method also eliminates a considerable number of connections. Remington Rand is employing this type of thin-film circuitry in its UNIVAC 1107 computer and other manufacturers will soon use it also.

<u>Molecular electronics</u>. Molecular electronics is a new concept and is the ultimate in simplicity of electronic circuits. Basically, molecular electronics integrates into a single block of material the functions performed by many electronic circuits or even whole systems. This is accomplished by re-arranging the internal physical properties of the solid in such a way that phenomena within or between domains of molecules will perform a function ordinarily achieved through the use of an assembly of electronic circuits. Molecular electronics is the most forward looking of the several approaches to the development of small, reliable, efficient electronic systems, and is unique in that it will eliminate the traditional circuit components. Molecular electronics will not only improve reliability, but it will also reduce size, weight and power requirements of computers still further. It will also make possible the

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execution of tests which are now too complex to be economically performed by conventional circuits.[75] Westinghouse Electric Corporation is now developing a molecular computer nicknamed "Mol-E-Com", which will weigh less than 15 pounds and occupy less than one-third of a cubic foot of space.[76] A transistorized model of equal capability would weigh 175 pounds and take up three cubic feet of space.

Cryogenics. Cryogenics utilizes the low temperature superconductive properties of matter that are displayed when temperature ranges are maintained from -200 degrees F down to -415 degrees F. The cryogenic device with the most promise is a switching device called the cryotron. Under the cryogenic concept, the entire computer except the input and output would be made up of cryotrons and would be kept under liquid helium refrigeration. The refrigeration of a computer would not be a problem since modern cryogenic techniques have shown that such systems can be made reliable over running periods of a thousand hours or more. However, the refrigerator's requirements would limit the smallest size of computer that could be manufactured. The advantage of cryogenics

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[75] "Molecular Electronics-An Introduction-Westinghouse Electric Corporation," Computers and Automation, Vol. II No. 3, March 1962, p. 10.

[76] "Westinghouse Developing Molecular Computer," Armed Forces Management, Vol 7 No. 10, July 1961, p. 59.

is that at these low temperatures, the molecules cease to move and this results in abnormal resistance to wear or failure. It is interesting to note that those who have worked on the cryotron are so confident of its ultimate success, that a considerable amount of work has already been devoted to the design of cryotron computer networks even before the full range of cryotrons are available.[77]

On line servicing and alternate path techniques. Two other techniques that will be employed in the near future to increase reliability are on line servicing and alternate path techniques. The use of extensive on line testing and checking circuits will reveal malfunctioning circuits or even weak circuits before they fail.[78] This will allow replacement of weak circuit cards before the failure occurs. At the same time, progress is being made toward building computers that will be able to select alternate paths in the event of malfunction of the circuit. Then at inspection periods the circuits may be tested and weak and inoperative circuit elements replaced.

Redundancy. Under the redundancy principle a duplicate

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[77] J. M. Lock, "Towards Superconductive Computers," Cryogenics, Vol. 2. No. 2, (December 1961) p. 65.

[78] Rex Rice, "Computers of the Future," Proceedings of Eastern Joint Computer Conference, Vol. 16, (December 1-3 1959).

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system, equipment, component, circuit or element is provided in case of failure of the normal device. Redundancy of internal circuits and critical elements is not expensive and reduces the probability of failure by the square of the original probability. For example, if the probability of failure of an equipment is .01, and if a redundant equipment is provided, the probability of failure is decreased to .01 x .01 or .0001. Thus redundancy is an inexpensive method of sharply increasing reliability.

Unfortunately, the reliability of the peripheral equipment is not as high as that of the computer itself. One reason is that most of this equipment has high speed moving parts, some of which must constantly maintain very small clearances. However, these devices are no more complicated than other electronic, teletype or fire control equipments that have been aboard Navy ships for years. Thus, it can be expected that there would be more maintenance problems with the peripheral equipment than with the computers themselves, and ships would have to be provided with the repair parts and trained personnel to service the peripheral equipment.

## V. PROGRAMMING

In order to obtain the optimum results from afloat electronic data processing, it would be necessary to standardize operating procedures and programs for routine data

processing. Therefore, the development of all programs for shipboard computers would be accomplished at the Fleet Computer Programming Center, Pacific or the Fleet Computer Programming Center, Atlantic. All ships would thus operate under the same programs. The respective Fleet Computer Programming Centers would initially furnish each ship with two copies of each program on magnetic tape. One set of tapes would be filed aboard ship, in the event the set of programs in use were damaged or inadvertently erased. In this case, another set of duplicate programs could be reproduced from the file copy. If, due to unusual circumstances, both copies of the program were lost, the ship could obtain copies of the programs from ships in company.

It is to be noted that this system assumes that all ships would be equipped with compatible computers which had similar characteristics so that it would only be necessary to develop one set of programs. The importance of this assumption will be discussed in Chapter V.

The Fleet Computer Programming Centers should be assigned the duty of not only initially developing the programs, but constantly reviewing them, improving them and updating them as necessary. These Centers should be furnished advance copies of all changes to procedures or regulations that would affect data processing for all departments of the

ship. Thus the Centers could incorporate these changes as necessary in the respective programs. All changes in material identification media (stock number changes, price changes, etc.), corrections to charts and publications, field changes and similar information should be furnished to these Centers in order that they could match the change against the latest library tape from the ship. The Centers could then punch a tailored paper tape of all the changes that affect a certain ship and mail these changes directly to the ship. To effect the changes, the ship would merely use the tape as an input to its computer and all records would be updated simultaneously.

All programs written by the Centers would be coordinated with the appropriate office and bureau to ensure that adequate audit trails were provided. However, to preclude defeat of the benefits of computers aboard ships by bureaus and offices which require unreasonable audit trails, it would be necessary that Navy wide requirements be established and promulgated by the Secretary of the Navy.

Although ships would not be permitted to write their own programs for routine data processing, they should have the capability to write their own programs for tasks peculiar to or specifically desired by the command. Fleet schools at the Computer Programming Centers should be expanded to include several courses, including data processing, tactical and

scientific problem programming. The capacity of the schools would have to be increased in order to train as many fleet personnel as possible.

Routine programming is a long and tedious task, but not a difficult one. In fact, the University of Maryland has trained twelve talented students from a nearby Washington, D. C. high school in programming the IBM 709 and 1620 computers.[79] However, since it is a long time consuming job most programming should be accomplished ashore. In this manner, one team of programmers could perform the task that would otherwise have to be performed by a team of programmers on every ship. A book of optional skeleton programs, or program segments (sub-routines) could be furnished each ship and the afloat programmers could complete the program they desired by using the skeleton program and segments as guides. Thus, programming would not be a major obstacle in the path of afloat electronic data processing.

## V. PSYCHOLOGICAL CONSIDERATIONS

The psychological considerations involved in installing electronic data processing aboard ship are extremely critical and their importance should not be underestimated. Many of the so-called failures of computers to do the job that had

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[79] "High School Students Learn Programming," Data Processing, Vol. 3 No. 11, (November 1961), p. 64.

been planned for them was not the fault of the computer but of management and the personnel in the firm or activity. Human beings resist change, especially when the change involves a machine that can do their job better than they themselves can do it. It hurts their pride and they fear it will hurt their pocketbook. The Navy man is no exception. Accordingly, before any computer is placed aboard ship, the personnel concerned must be carefully conditioned for the event. Likewise, every officer in the Navy must be conditioned for the "computer age" if the Navy is to take full advantage of the advances in technology which it must.

When asked to investigate the feasibility of computers aboard ship, the writer scoffed at the very thought. Computers would never have a place aboard ship! However, it was not long after the writer started investigating the matter that he realized the almost unlimited possibilities of the computer and made a 180 degree about face.

The writer wrote the Supply Officers of seventeen ships which had electric accounting machine equipment installed and asked for their ideas on electronic data processing afloat. All officers reported that the Supply Department had to have automatic data processing equipment of some sort to get the job done, but not one officer was enthused with the use of computers afloat and many were even skeptical of its value.

In the course of conducting this study, the writer discussed EDP afloat with many of his contemporary officers. When asked what their ideas were on EDP afloat, they were taken completely by surprise and indicated that they had never thought about it and didn't think it had any application.

The editor of Armed Forces Management set forth the same feeling when he stated

> Their (Defense EDP people) chief complaint is that top management is still trapped in a sort of cultural lag over just what the computer can mean to an operation--We can crank out the answers with very little trouble-once management recognizes the problem is one a computer can solve--Many operations now on computers still have a series of duplicative manual operations hanging on their coattails apparently because the CO doesn't quite believe his new toy can do the job.[80]

This same story is echoed again in a recent article in the U. S. News and World Report which stated

> In the Pentagon and in the field, it is claimed, influence over big decisions on U. S. defense is now passing away from military men into the hands of a "scientific elite."
>
> These scientists as seen in action are armed with high speed computers, versed in qualitative analysis and in their own view, almost alone able to cope with the complexities of modern war and weapons.
>
> Military men accept the need (for computers) yet concern is heard that as machines continue to take over, some traditional functions of command are passing to

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[80]Bill Borklund, "The Price of Progress," Armed Forces Management, Vol. 7 No. 10, (July 1961), p. 5.

the scientist. Some military men claim they are being put in "computer strait jackets".[81]

These statements corroborate the writer's findings that there is a severe "computer culture vacuum" within the Navy which must be quickly filled if the naval officer is to maintain his authority to manage and command. This problem is not unique to the Navy. Industry has faced the same growing pains problem but was quick to recognize it and seek a cure. When the Richfield Oil Company in Richmond, California recently installed a computer on which to simulate the complete company operation, they sent all of the company's top management including the President and all Vice Presidents to a two weeks indoctrination school at the International Business Machines Incorporated plant at San Jose, California.[82] This was followed by indoctrination school for middle management. This training laid the groundwork for further training of management at the plant and the vigorous and continuous training and indoctrination of subordinates by management. Most industries have found it necessary to take this approach since lack of understanding by management will often nullify any benefits to be obtained from computers.

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81"Will Computers Run Wars of the Future," U. S. News and World Report, Vol. LII No. 17, (April 23, 1961), pp. 44-48.

82J. J. Doubt in a speech at IBM plant San Jose, California, March 23, 1962.

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The naval officer or the petty officer with fifteen or twenty years service has lived a life steeped with tradition, symbolism and pride in the history of the Navy. Likewise, naval personnel have been trained over the years to follow a prescribed routine and to react uniformly to similar situations. However, these traits which were held in so high esteem have also fostered a severe resistance to change in the average Navy man. Consequently, it will not be an easy task to sell electronic data processing to the sailor.

The Navy, like industry, must start this change to a new Navy from the top. When the airplane proved that it had a place in the Navy, many flag officers and senior officers entered flight training and earned their "wings of gold." Now that the computer and management science are establishing themselves in the Navy, the same procedure must be adopted. Flag and senior officers must be indoctrinated and convinced of the ability of the computer and they in turn must convince their subordinates that if the Navy is to maintain its reputation it must adapt itself to the most advanced sciertific techniques. In this connection, naval personnel must be convinced that computers will become the tools of all naval personnel, just as fire control computers became the tool of the gunners. They must be convinced that computer knowledge can not be left to a special few, and that all personnel must know how to use computers in their daily work if they are to be successful

managers and leaders.

It must be concluded that there is at present a severe "computer culture vacuum" in the Navy, which must be filled if computers are to be used successfully aboard ship. The quickest and most efficient way to correct this serious shortcoming is to indoctrinate the senior officers first and let the culture run downhill as rapidly as possible.

## VI. TRAINING CONSIDERATIONS

The Navy's efforts in training its personnel in the use of computers has not kept pace with the technological progress in the manufacture of the product. This has also been true of industry, and today both industry and the Navy must quicken the training pace appreciably if they are to properly utilize the tools being made available. It has been estimated by the Association of Computing Machinery that 200,000 programmers alone will be required in the next decade to meet the demands of business, industry, government and research.[83]

Training can be divided into three technical degrees; namely, familiarization, operational and technical, and into four classes of trainees; namely, flag and senior officers, junior officers, midshipmen in training for commissions and

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[83]"High School Students Learn Programming," Data Processing, Vol 3 No. 11, (November 1961), p. 64.

enlisted personnel. Obviously, every officer doesn't have to have a Master's degree or have the technical knowledge of the internal mechanisms of a computer, but some should. Likewise, some medical officers should only be familiar with the computer and not be involved in its operational use, while others should be technically qualified. Accordingly, the Navy should aim at familiarizing 100% of all personnel, training 75%-85% of all personnel in the operation of computers, and from 10%-20% of its personnel should receive technical training at the postgraduate level.

The training program should be very carefully coordinated to insure that the objective is accomplished, without leaving a "bitter taste" in a person's mouth. Personnel must be won to the new Navy and the new way of doing things, or else the Navy will receive serious setbacks.

The training program should start at the top with the flag and senior officers being offered indoctrination courses commensurate with their rank and experience. Then the junior officers should be subjected to a more rigorous training which would be conducted at fleet training activities and at the postgraduate level. Meanwhile, the present schools for enlisted personnel should be expanded and carefully prepared shipboard training programs instituted. Senior officers should be encouraged to stress the new sciences to their juniors and the division officer to his division.

The required curriculum for Midshipmen should also be reviewed to ensure that future officers become proficient in the disciplines and tools that they will be using in the fleet. It is noted that the U. S. Naval Academy offers courses in Digital Computers, Analog Computers, Matrix Theory and Probability and Statistics.[84] However, these are elective courses and not required courses. This would indicate that the U. S. Naval Academy curriculum should be reviewed in an attempt to give the Midshipmen more training in the computer and management science area. NROTC Midshipmen should also be required to take similar courses if they are offered at the university or college they are attending.

In conclusion, the present state of training would barely sustain the scheduled influx of computers into the fleet today. Immediate action to expedite the training of personnel would have to be taken if the present installation schedule were accelerated.

## VII. PERSONNEL CONSIDERATIONS

The Navy of the future will require fewer but more highly trained personnel. Computers and automation in the naval vessel are imminent. Imagine the impact on the

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[84] Catalogue of the Course of Instruction at the U. S. Naval Academy, 1960-61, p. 28, 29.

submariner if Project Subic proves successful in reducing the crew of an atomic powered submarine from 100 to 12 men.[85] Even the surface ship sailor is not secure, for Project Suric is aimed at automating a destroyer escort and drastically reducing crew requirements for destroyer type vessels.[86] Assuming these projects prove successful (and there is no reason to doubt that they shouldn't, since computers are controlling complete factory processes ashore) the reduction in personnel requirements of the Navy will gradually approach the fifty per cent mark. So the introduction of the computers aboard ship will have very serious personnel implications.

A very real personnel problem that must be faced now is the upgrading of the average intelligence of naval personnel in order to preclude excessive personnel turnover later. The Navy has already experienced this problem with the electronics technician and the maintenance of electronic equipments. Rear Admiral Fahy, Chief of the Bureau of Ships, recently reported that the skill levels and the numbers of electronic technicians available are not adequate for the maintenance of many equipments.[87] Rather than maintenance, the new problem

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[85]"Project Subic," Naval Research Reviews, August 1959, p. 3.

[86]"Project Suric," Naval Research Reviews, October 1960, p. 6.

[87]Rear Admiral E. J. Fahy, USN in a speech at the U. S. Naval Postgraduate School, Monterey, California, May 2, 1962.

will be training people in computer technology and keeping them in the service. For as the computer assumes the routine clerical job of an individual, the latter will have to be trained in more sophisticated and intellectual tasks. If the replaced person does not have the intelligence or background to acquire these new skills, he will have to be released and replaced by a person who has the necessary requisites. Meanwhile, industry will be experiencing the same shortage so that any person who becomes highly trained in computer technology will be in great demand in industry as well as the Navy. Accordingly, appreciable additional monetary compensation will have to be offered personnel in order to retain their services in the military service.

The introduction of the computer aboard ship will start a trend toward automation which will have severe implications. While the problem is not insurmountable it is one that must be faced now and faced squarely. A plan must be developed to reassure personnel concerned that their livelihood and future is not at stake. If the impact of computers is to be minimized this plan must be far reaching and it must start now. It must provide for the upgrading of the average intelligence of naval personnel, it must consider reduction of personnel by attrition and early retirement, it must anticipate changes in organization and rank and rating structure, and it must

take into account greater monetary compensation of the individual.

## VIII. ORGANIZATIONAL CONSIDERATIONS

If an electronic data processing system is installed aboard ship, current organization and procedures would have to be reoriented in order to obtain maximum benefits from the computer. This would require changes in both the ashore and afloat organization.

<u>Ashore.</u> Optimum efficiency would be realized from an electronic data processing system only when as many different procedures and systems as possible were integrated and standardized into one standard procedure. Any exception to a standard routine would require a separate computer program with the concomitant inefficiency of separate computer runs and more computer time. Consequently, procedures peculiar to one management bureau such as methods of issuing changes to publications, methods of promulgating changes to installed equipments, procedures for maintaining machinery and equipment histories, methods of reporting casualties to equipments and methods of providing repair part support to equipments would have to be standardized for all equipments, ships and bureaus. This would require coordination of all the management bureaus and possible

reorganization of some shore activities.

*Afloat.* An organization must be designed to accomplish efficiently the work that must be performed. The present shipboard organization is based on the administrative workload of the various departments and, by and large, the separation of the ship into administrative departments is required to provide proper supervision of groups of persons performing different tasks. When the duties of the individual departments are changed, the organization must be changed to reflect the new requirements of each department.

If a computer and an EDP system were installed aboard ship, the shipboard organization should be changed if the ship were to derive the maximum benefits from the computer. This new organization should take into consideration that the data processing group would cross all departmental lines, that it would provide services to all departments and that it should have the organizational strength to make decisions or compromises as to which task for which department would receive priority. These criteria would of necessity make it desirable organizational-wise to have the data processing group as near to the command as possible, in a staff position and above the normal line of department heads.

The officer designated to head the data processing department should be one who is most familiar with the processing of

large amounts of data and he should also be one who is experienced in heading up a service or staff activity that is already engaged in rendering services across departmental lines. Since the data processing center will be working at least sixteen hours a day, the head of the data processing department should be available at any hour of the day and should therefore not be required to stand regular underway and in-port watches.

On most ships, the tactical data system will require all the time of the Operations Officer, while the Gunnery Officer and Engineering Officer will be preoccupied with the computers and equipments associated with their respective departments. Accordingly, the Supply Officer would be the only department head available to head up the data processing group. This designation would not prove incompatible with the requirements set forth in paragraph three above, and the Supply Officer would be a logical choice when it is considered that the vast bulk of the data processing shipboard workload would be supply and personnel actions with which he is already quite familiar. The designation of the Supply Officer as head of the data processing department would also be in consonance with the practice in industry where it has been determined by experience that the most logical location for the data processing center is in the finance area under the controller

or chief accountant.[88]

To fully utilize EDP afloat all data processing would be integrated and all duplication of effort should be eliminated. For example, if a man reports aboard ship for duty, one input should be made into the computer and this one entry would update all ship's records simultaneously including personnel records, medical records, pay records, division records, liberty lists, and watch quarter and station bill. If a part is drawn from the storeroom to repair a particular equipment, one entry into the data processing system must update the stock records, record the expenditure to the departmental budget, the ship's OPTAR, the maintenance history of the equipment concerned, charge the work to the record of the person making the repair and reorder the part as necessary.

Therefore, if a computer were installed aboard ship for EDP purposes and it was desired to obtain optimum use of the computer, the present shipboard organization should be changed to reflect the integration effected. This new organization would place the Supply Officer as head of a department that should be called the Logistics and Services Department.

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[88]E. Wainright Martin, Jr., Electronic Data Processing (Homewood: Richard D. Irwin Inc., 1961), p. 345. Stanford L. Optner, Systems Analysis for Business Management (Englewood Cliff: Prentice-Hall Inc., 1960), p. 602.

This department would be placed in a staff position reporting to the Executive Officer. The Logistics and Services Department would control all those persons offering services to other departments. These services would include the following:

a) Logistic support in general
b) Technical repair parts support
c) General stores support
d) Commissary
e) Ship's Store and Clothing and Small Stores
f) Disbursing
g) Personnel
h) Mail and routing
i) EDP

At first glance it would appear that the Logictic and Services Department would be a large and unwieldy group. However, it must be remembered that after the computer is installed and functioning properly, the allowance structure of this department could be reduced by approximately two thirds.

The Logistics and Services Officer would be responsible for all supply support of the ship including ammunition and medical supplies. This would require certain medical, engineering, electronic repair and gunnery personnel to be assigned to the Logistics and Services Department for maintenance of their respective storerooms and liaison with their respective departments.

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# IX. SUMMARY

It must be concluded that a computer and the attendant peripheral equipment can be accommodated aboard ship providing certain changes and advance preparations are made. Size, weight, maintenance and programming would create no problems. It would be necessary to air condition the computer center and it would be necessary to establish concentrated electronic data processing system training courses ashore.

In order to obtain optimal efficiency from the afloat electronic data processing system it would be necessary to change the current shipboard organization and place all personnel rendering services to other departments in the Logistics and Services Department. This department would function in a true staff concept and report to the Executive Officer.

The maximum cost of the complete installation would not exceed three hundred thousand dollars. In most ship types, the savings resulting from the reduction of personnel allowances as a result of the installation of EDP would more than cover these costs. However, the actual overall benefits to the Navy that would be achieved by installing EDP afloat would dwarf the actual cost of installation and the subsequent

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cost of operation.

The greatest deterents to the installation of EDP afloat are the psychological and personnel considerations. The fleet is not conditioned to the computer. The indoctrination and education of naval personnel in the computer and its applications has not kept pace with the advances in technology and hardware. Accordingly, a severe "computer culture vacuum" has been permitted to form. This is the most serious obstacle to the success of EDP afloat.

While there are some obstacles to be hurdled and some changes and advance preparations to be made, these are not insurmountable problems. Since these problems will have to be addressed and resolved in the course of the installation of the NTDS in all major combatant ships, there is no reason why electronic data processing can not be accommodated aboard ship.

# CHAPTER V

# SELECTION OF THE COMPUTER

The selection of a computer and the associated peripheral equipment is an important and critical decision. This selection must be based on three criteria of equal importance. These are:

a) Will it efficiently accomplish the required shipboard data processing tasks?

b) Is it compatible with and are its characteristics similar to other shipboard computers?

c) Is it compatible with the computer networks with which it will be required to communicate, and is it compatible with the communication links to these networks?

The effect of each of these criteria on the selection of a computer and its peripheral equipment is discussed in the following paragraphs.

## I. REQUIREMENTS FOR EFFICIENT SHIPBOARD DATA PROCESSING

A computer installed aboard ship for data processing purposes must be capable of performing a wide variety of tasks. The bulk of these tasks is as sophisticated or even more sophisticated than similar processes in industry. Accordingly, particular care must be exercised to select the computer that will perform all these requirements in the

most efficient manner possible. The most important characteristics of the desirable computer are discussed in the following paragraphs.

General characteristics. The computer selected for shipboard data processing should be a rugged, compact, small or medium size, extremely flexible, general purpose digital computer capable of real time operation. It should have its own self contained air conditioning or not require air conditioning so that continued operation of the computer is possible in the event of the failure of the shipboard air conditioning system. The computer should be designed and constructed on the basis of military specifications and of structural rigidity and appropriate shock mountings so as to withstand shipboard environment, including shock, vibration, dampness and rolling and pitching motion.

Word length. Since the word length of the computer determines the size of the number that may be stored in one memory cell and manipulated within the computer, it is essential that the word length be great enough to accommodate the majority of the data which will be processed. In many instances, the computer would have to manipulate stock numbers, service numbers and file numbers all of which are composed of seven to ten digits. It will also be necessary to manipulate

dollar amounts as high as one million. Consequently, it is essential that the computer have a minimum word length of ten digits or be capable of handling variable word lengths. The computer should also provide for operation with half words of five digits if variable word length is not possible. These word lengths would provide the most efficient data processing and would also provide for optimum utilization of core storage space.

Registers. Computers using registers should be provided with two arithmetic registers (Accumulator and Q register) with a capacity of ten digits so that numbers as large as 9,999,999.99 could be easily manipulated. The computer should also contain at least four index registers to provide for address modification.

Internal storage. The internal storage should be of the core storage or thin-film type and should provide a storage capacity of 32,768 ten digit words. This storage capacity is necessary in order to store the sophisticated programs required in shipboard data processing. Any lesser amount of storage capacity would require splitting the programs into two parts and making two computer runs for each transaction, or sorting transactions into specific transaction categories before processing them. In either case, computer time would be doubled. This minimum storage requirement is substantiated

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by the fact that the general stores and repair parts program now being evaluated aboard ship using the AN/USQ 20 computer contain over 30,000 ten digit words.[89]

In addition, a small auxiliary internal memory of sixteen to thirty two words should be provided to permit storing of certain important instructions or constants to facilitate rapid changes in the program and to facilitate program recovery as necessary.

Operating instructions. The computer should contain a repertoire of instructions that will provide all the normal arithmetic operations and in addition have the capability of address modification, program branching, masking, loop control, search operations, fixed point and floating point arithmetic. The basic instructions should number in the vicinity of fifty and should make programming as simple as possible.

Input, output channels. The shipboard computer should have a minimum of four buffered input and four buffered output channels for use with peripheral equipment. In addition, it should have two asynchronous input and output channels to be used in communicating with other computers.

The computer should be capable of utilizing magnetic

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[89]George S. Pope Jr., LCDR SC USN, in personal letter of 16 February 1962.

tape, five channel punched tape, and console typewriter as input, output methods. It should also be capable of communicating real time with other shipboard computers and should be equipped with appropriate interrupt features.

Maintenance and reliability. The computer should be designed to facilitate maintenance and insure reliability and peak operating performance. It should be simple to operate and provide rapid access to all portions of the computer. Circuitry should be completely solid state with an internal checking device and plug in circuit cards which would permit rapid replacement of defective circuits.

External auxiliary storage. External auxiliary storage for the shipboard electronic data processing system should be limited to magnetic tape or magnetic cards. Magnetic tape units would be required as a program input device so it would save space and funds to also use them for auxiliary storage. In addition, magnetic tape or cards are desirable because they provide the capability of having duplicate back-up tapes on the ship and facilitate furnishing duplicate master tapes to the Fleet Computer Programming Centers at San Diego, California and Norfolk, Virginia.

The magnetic card system similar to the National Cash Register Card Random Access Memory (CRAM) System is superior

to the reel tape system. The former provides random access to the records thus increasing the speed of operation and it also eliminates the problems involved in having more data to put in a storage block than available blank space in that block.

Each card has seven tracks of magnetic tape and each track has a capacity of 3100 alphanumeric characters.[90] There are 256 cards in the cartridge in each card handler. Since the average word length is less than five letters, each track on the card has a capacity of 620 words, each card has a capacity of 4340 words and each cartridge has a capacity of over one million one hundred words.[91]

Accordingly, under the integrated system and using magnetic tape cards, one track containing 620 words could be assigned to each equipment history record and the master inventory record of each fast moving item. One card containing 4340 five digit words could be assigned to every two individuals. This card would contain the complete history of the individuals including personnel record, leave record, pay record, training record, and duty assignments.

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[90]"Card Random Access Memory File 353-1," NCR 304, 315 and 390 Electronic Data Processing Systems Authorized Federal Supply Schedule, p. 19.

[91]Edward M. McCormick, Digital Computer Primer, (New York: McGraw Hill Company, 1959), p. 192.

## II. COMPATIBILITY WITH OTHER SHIPBOARD COMPUTERS

The computer that is selected for installation in ships must not only be compatible with other computers on that particular ship, but it must also be compatible with the computers in the entire fleet as a system. That is, the output of one computer should be capable of being used as an input of all others without any conversion from one form to another.

Even more important than compatibility per se is the fact that certain characteristics of the computers must be similar if maximum gains are to be realized by the computer installations. If computers with different word lengths, different instruction repertoires, different numbers of index registers, different size arithmetic registers and other disconformities, were installed in the ships, a great amount of work and effort would be duplicated. For example, different characteristics such as those enumerated above would require that a different program be written for each procedure for each type computer. An alternative would be to write one program that only utilizes the minimum characteristic capabilities of the different computers. This is also unsatisfactory since it does not take full advantage of the capabilities of the individual computers.

Likewise, different types of computers would require different repair part support, would require personnel to be trained to maintain and operate several systems rather than one, and would make standardization of procedures impossible.

Obviously, if shipboard systems and procedures were to be standardized so must the computers which must process the data in accordance with these systems and procedures. Furthermore, if dissimilar computers were installed in the ships, this would eliminate any anticipated savings since the paperwork generated by the different type computers would become more than that eliminated. Therefore, if maximum benefits are to be obtained from electronic data processing, the ultimate goal must envision computers installed on all ships that are not only compatible but that also have similar programming characteristics.

## III. SYSTEM COMPATIBILITY

The shipboard computer must also be compatible with the computers ashore with which it will be linked and the communication nets that will link these computers to the ashore network. When operating at sea all reports or requests for material that can not be held until return to port will usually be transmitted by radio teletype, which utilizes five channel coded paper tape as an input and output media. Likewise, when

in port, five channel paper tape can be retransmitted by data phone or delivered to a designated shore activity for transmission to the addressee by the Rapid Data Transmission System. This service also utilizes five channel coded paper tape for input and output media. Accordingly, the computer installed aboard ship for electronic data processing must be capable of using five channel tape as an input and output device as long as the communication systems utilize five channel tape.

The shipboard system should also have the capability of utilizing punched cards as an input and output medium. However, under the proposed system, a tape to card and card to tape converter would be provided that would convert, off line, the five channel tape to cards and vice versa. Consequently the computer itself need not have this capability.

## IV. AVAILABLE COMMERCIAL COMPUTERS

The writer solicited information and technical data from eighteen U. S. manufacturers of digital computers and investigated all commercial computers on the market. While many of these computers fulfilled many of the minimum requirements set forth earlier, not one of the computers met all the necessary requirements for an efficient shipboard data processing computer. In fact, it is noted that even the AN/USQ 20

now being installed aboard naval vessels as part of the NTDS has a characteristic that is a serious obstacle to an integrated data processing system. This is the fact that the AN/USQ 20 utilizes six channel paper tape for input and output which makes it incompatible with the ship's radio teletype and RDTS. It is also noted that the AN/UYK-1, another computer being installed in naval vessels, has the following deficiencies:

1. The word length of the arithmetic register is only five digits.
2. The internal core storage has a capacity of 32,768 five digit words which is only half of the required storage capacity.

## V. COMPUTER PROCUREMENT

It was pointed out earlier that any computer installation must be planned on a system wide concept. In the case of ships, where programs and procedures must be standardized, this total system concept is even more important.

The AN/USQ 20 computer is now installed on five ships of the fleet, and it is scheduled for installation on all major combatant ships of the size of the DLG and up. Supply Department data processing programs have already been written, debugged and placed in operation using this computer. Therefore, it is certain that it can do the job. This computer is the heart of the NTDS system, and if it is inoperative the

whole system in inoperative. Since so much reliance is placed on this system, it appears unduly risky to have only one computer installed on some ships and on other ships to have them all located in one area where they all might be made inoperative by a single casualty. There need be no concern over the reliability of the computer itself, but other conditions such as battle damage, fire, storm, flooding, or cable damage could make the computer or computers inoperative and thus put the NTDS system out of operation. Accordingly, it is recommended that on ships with multiple AN/USQ 20 installations, one computer be located in the Data Processing Center which would be physically separated from the other computers, and in the case of single AN/USQ 20 installations, a second computer be installed and located in a Data Processing Center which would be physically separated from the other computer. In all cases, the AN/USQ 20 in the Data Processing Center would be tied into the NTDS system with the capability of automatically interrupting any operation in process in the Data Processing Center.

The advantages of this system are many.

1. A back-up computer would always be available for the NTDS system.

2. Since only one model computer would be aboard ship rather than two

   a) repair part support would be minimized.

   b) training requirements would be minimized.

c) programming and procedure costs would be minimized.

3. Standardized systems and procedures would be possible.

It is strongly recommended, however, that a study be conducted to determine the feasibility of converting the AN/USQ 20 from a six channel paper tape system to a five channel paper tape system. If the conversion is not feasible, six channel tape would have to be converted to five channel tape and vice versa by an off line process. Commercial tape to tape translators are available.

Since no entirely suitable computer is available commercially, it is recommended that a computer built to Navy specifications be procured for those ships without an NTDS system and for those ships with an NTDS system but for which it is considered impractical to install the AN/USQ 20 computer for data processing. The specifications for this computer would include the minimum characteristics cited earlier and should ensure that general procedures and programs that apply to the AN/USQ 20 also apply to the new computer.

## VI. PERIPHERAL EQUIPMENT

The following peripheral equipment all of which is available commercially would be required:

a) One paper tape read-punch unit
b) Two read-write magnetic tape units.
c) Two Flexowriters.
d) One off line tape to card, card to tape converter.

A high speed printer is not essential to the system, but would be desirable. These are also available commercially.

There is still one weak link in the shipboard data processing system. This is the fact that raw data must still be transferred to machineable format by humans and thus human errors are bound to creep into the system. Consequently, there is an urgent need for a low cost optical character reader that will take data from the raw document and automatically enter it into the computer or at least transform it to machineable format. The writer solicited information from several computer and office equipment manufacturers as to whether any such device was near the production stage, but all were noncommittal. The various trade journals also stress the need for such a device and it is just a matter of time before a reasonably priced optical character reader will be placed on the market. At that time it too should be added to the shipboard peripheral equipment.

## VII. SUMMARY

A computer that meets all the minimum requirements for an optimum shipboard data processing system is not available commercially at this time. It is recommended, however, that

on ships with multiple AN/USQ 20 installations, one computer be relocated to the Data Processing Center. On ships with only a single AN/USQ 20 computer, it is recommended that a second computer be installed as back up for the primary NTDS computer and for data processing. In both cases, the Data Processing Center would be physically removed from the present NTDS installation to provide emergency service in the event of battle damage or other casuality to the primary AN/USQ 20 computer or computers.

For ships without an NTDS computer system, it is recommended that computers be procured on a contract basis in accordance with specifications provided by the Navy. These specifications would include the minimum characteristics cited earlier and should ensure that the general procedures and programs that apply to the AN/USQ 20 also apply to the new computer.

The following peripheral equipment which is available commercially would have to be provided each ship.

a) One paper tape read-punch unit.

b) Two magnetic tape units.

c) Two Flexowriters.

d) One tape to card and card to tape converter.

# CHAPTER VI

# SUMMARY AND CONCLUSIONS

## I. SUMMARY

The effects of the current technological revolution, the efforts of the Department of Defense to integrate the stocks of material of the four services, the current operations of the fleet under accentuated readiness conditions, the new techniques of management science and the increased workload of the shipboard Supply Department have made it essential that all departments of the ship and particularly the Supply Department, be provided with the necessary tools to allow them to perform their assigned missions efficiently. Reduced preparedness and military capability will result unless a solution is provided for the ever increasing shipboard workload problem. As automatic systems are added to the ships, the crews will be reduced but the paper work will keep mounting. This will place the shipboard manager in an untenable squeeze between a rapidly increasing work load and decreasing numbers of personnel to process it.

Industry and the military services ashore are using the computer and electronic data processing to solve the increasing paperwork problem. The Army and the Air Force are providing computers to perform electronic data processing in the field but the ships are still using the tools of World

War I, the adding machine and typewriter.

A review of the current shipboard data processing workload and the capabilities of existing computers indicates that at least 75% of the paperwork could be accomplished by electronic data processing. Not only would the computer permit the ship to process data more accurately and more quickly, but it would allow it to perform tasks that were impossible under a manual system.

The review also revealed that to obtain maximum economy and efficiency, the shipboard data processing system must be designed on a Navy wide basis and must be an integrated system that crosses management bureau and shipboard departmental organizational lines of authority. While the ashore activities appear to be developing EDP on a Navy wide basis, the ship has been the forgotten link in the chain.

The computer and its peripheral equipment can be accommodated aboard ship providing certain advance preparations are made. The size, weight, maintenance and programming of the computer would impose no problems. It would be necessary to air condition the computer center, and it would be necessary to establish additional EDP training courses ashore.

In order to obtain optimal efficiency from the afloat electronic data processing system, it would be necessary to change the current shipboard organization and place all

personnel rendering services to other departments under the Logistics and Services Department which could be headed by the Supply Officer. This department would function in the true staff concept and report directly to the Executive Officer.

Under the "program package" budget concept, operating as well as installation costs must be considered in any budget item. The maximum cost of the complete shipboard EDP installation would not exceed three hundred thousand dollars per ship. In most ship types, the savings resulting from the reduction of the personnel allowances as the result of the EDP system would more than cover these costs. The greatest portion of the annual operating costs, personnel, have already been taken into consideration under installation costs, when the savings to be realized for each person removed from the shipboard allowance was reduced by one third. This was based on industry experience that for every three persons replaced by EDP, one person must be hired to operate or support the equipment. The remaining annual operating costs would be more than recouped by the indirect savings to be realized by installing EDP afloat including the decrease in pipeline personnel and material, decrease in workload of shore activities, reduction in afloat file storage space and office equipment and improved inventory control. However, cost itself should not be the only criterion. EDP afloat should not

be measured solely on economic grounds but also on its contribution to the military operational capability of the fleet. In the case of shipboard EDP, the actual overall intangible benefits to be derived by the Navy [illegible] the actual costs of installation and operation.

In order to realize optimum efficiency, computers installed aboard ship for data processing must be compatible with other shipboard computers in the fleet, computers ashore with which the shipboard computer will communicate and the communication systems connecting these computers. Even more important, shipboard computers must have similar programming and operating characteristics in order to eliminate the need for duplicate programs, duplicate maintenance procedures, duplicate training effort and duplicate operating procedures.

There is no computer available commercially that will fulfill all the characteristics required of a shipboard computer in order to obtain the most efficient data processing system. A recommended solution in the case of ships with the NTDS installation is as follows:

a) In case of the multiple installation of AN/USQ 20 computers, relocate one computer to the Data Processing Center.

b) In the case of the single AN/USQ 20 installation, install a second AN/USQ 20 computer in the Data Processing Center.

This recommendation has the advantages of ensuring a back up computer for the NTDS system and ensuring that similar computers are installed on most ships thus permitting maximum efficiency and economy.

In the event that this recommendation is unacceptable and for ships without an NTDS installation, computers conforming to Navy specifications as to construction and characteristics should be procured on a contract basis. The characteristics should comply with the minimums set forth in Chapter V and operating procedures should be similar to those of the AN/USQ 20.

The greatest deterents to the installation of EDP afloat are psychological and personnel considerations. The fleet is not conditioned to the computer. The indoctrination and education of naval personnel in the computer and its application has not kept pace with the advances in technology and hardware. Accordingly, a severe "computer culture vacuum" has been permitted to form. This is the greatest obstacle to the success of EDP afloat.

## II. CONCLUSION

Shipboard EDP is economically and organizationally feasible and will enhance the readiness position of the fleet. While there are some obstacles to be hurdled and some changes and advance preparations to be made, they are not insurmountable

problems. These same problems will have to be addressed and resolved in the course of the installation of the NTDS in all major combatant ships.

## III. IMPLICATIONS

There appears to be a growing trend to install on ships, different type computers for various purposes without regard to standardization of characteristics, maintenance or operating procedures. Although the computers might be used for fire control purposes, navigation, tactical data systems, command and control systems, they all work on the same principle and they all require programming, maintenance, training of personnel and standard operating procedures. Appreciable economies could be realized by standardization wherever possible.

If the reader will review Chapter II or browse through any of the data processing or computer trade journals, it will become quite obvious that the question of whether EDP will find a place in the shipboard organization has already been answered. The only question that remains is whether the Navy will start promptly and carefully to plan the conversion in a neat, economical, orderly method or whether the awakening will be delayed until a crash project will be required to prevent the floundering of the ships in a sea of paperwork.

## IV. RECOMMENDATIONS

This paper has just scratched the surface of the possible advantages to be obtained from afloat EDP. The present methods of writing programs for each department separately, based on present procedures, is heartening but this procedure has ignored a total system concept. It is recommended that a committee be established to perform a complete system analysis of afloat data processing from its conception to destruction. The committee should consist of representatives of the appropriate management bureaus and operational commanders. The study should start with the procedures, routines and reports that will be required of ships by the bureaus and operational commanders assuming that shore data processing networks are in fact established and that they can communicate with the ships' computers. Complete disregard should be given to present procedures. It should first be determined what is required of the ship by the bureaus and operational commanders, considering the ship as a black box. The committee should then go into the black box and determine how the ship can best furnish this information regardless of departmental organization. Shipboard organization should then be realigned to best administer the tasks required and standard procedures promulgated. Integration and standardization should be the watch words. For example, a standard machine history record

format should be established for every piece of equipment on the ship whether it be a radio, a missile launcher, a feed pump, or an anchor windlass. Likewise, all data regarding an individual should be maintained at one point in the organization, whether it be pay, leave, training, personal history or medical data. As soon as the system analysis is complete, a computer should be selected and programming commenced.

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# APPENDIX

The Bendix Corporation EDP System

BENDIX G 15D

| | | |
|---|---|---|
| 1 | Computer - Alphanumeric typewriter paper punch and reader | $ 51,000 |
| 4 | MTA - Magnetic tape units ea. $6,800 | 27,200* |
| 1 | Tape to card printing punch | 7,200 |
| 1 | Card to tape punch | 3,600 |
| 2 | Flexowriters ea. $2,900 | 5,800 |
| | Total | $104,800[92] |

* Small internal storage expanded by utilizing four instead of two tape units.

[92]Bendix Computer Division, The Bendix Corporation, Contract No. GS-00S-32087, July 1, 1960 to July 1, 1961; Gille Associates, Inc., Data Processing Equipment Encyclopedia (Detroit: Gille Associates, Inc., 1961, revised April 1962), pp. 17-51.

International Business Machines Corporation

Data Processing System IBM 1401

| | | |
|---|---|---|
| 1 | Processing unit (Model 1401 E6) | $128,950 |
| 1 | Additional storage unit (Model 1406) | 67,100 |
| 2 | Magnetic tape units (Model 7330) | 44,000 |
| 1 | Card read punch | 30,000 |
| 2 | Flexowriters ea. $2,900 | 5,800 |
| | Console inquiry unit | 8,350 |
| | Card to tape unit | 3,600 |
| | Tape to card unit | 7,200 |
| | Total | $295,200[93] |

[93]General Services Administration Contract, 6S-00S-34846, Gille Associates, loc. cit.

Radio Corporation of America

Model 301 EDP System

| | | |
|---|---|---|
| 1 | Basic Processor (Model 304) with 20,000 character storage | $112,900 |
| 1 | Paper tape reader-punch control (Model 311) | 5,900 |
| 1 | Paper tape reader-punch (Model 321) | 7,800 |
| 1 | Interrogating typewriter (Model 323) | 9,960 |
| 2 | Tape station (Model 581) | 59,400 |
| 2 | Typewriters (Model 523) | 5,640 |
| 1 | Card to tape punch | 3,600 |
| 1 | Tape to card printing punch | 7,200 |
| | Total | $212,400[94] |

[94]General Services Administration Contract, No. GS-00S-34853, July 1, 1961 to June 30, 1962; Gille Associates, loc. cit.

Thompson Ramo Wooldridge, Inc.

EDP System AN/UYK-1

| | | |
|---|---|---|
| 1 | Computer, including input/output controller, paper tape reader, paper tape punch and input/output typewriter | $108,200 |
| 1 | Expanded memory unit 24 K words | 110,000 |
| 1 | Magnetic tape controller | 25,000 |
| 2 | Magnetic tape units ea. $15,000 | 30,000 |
| 1 | Tape to card printing punch | 7,200 |
| 1 | Card to tape punch | 3,600 |
| 2 | Flexowriters ea. $2,900 | 5,800 |
| | Total | $289,800[95] |

[95] Ramo Wooldridge Division, Thompson Ramo Wooldridge, Inc., Price list of March 15, 1962; Gille Associates, loc. cit.

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